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Response to Oil Sands Products Assessment

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16. Abstract (MAXIMUM 200 WORDS)

Domestic production of crude oil in North America has increased at a tremendous rate. Oil sands products (OSP), such as diluted bitumen (Dilbit) from Alberta, Canada, are subject to spilling during transport to domestic markets and refineries in the U.S. via pipeline, tank cars, or marine vessels.

This report includes a qualitative risk assessment of potential spills of Dilbit and identifies initial response issues. Specifically, the following information, along with appropriate recommendations, are documented in this report:

- Geographic areas most at risk for spills and the prime routes of transportation in those areas.
- Techniques identified for response to surface oil and submerged oil spills that can address OSPs.
- Identification of what additional information the U.S. Coast Guard decision-makers need and what additional equipment or tactics responders need to prepare for Dilbit spills in waterways.
- How addressing these recommendations will provide more robust and safer response to future spills of Dilbit.
- A description of proposed tasks for future research efforts related to the recommendations.

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EXECUTIVE SUMMARY

The Athabasca oil sands in Alberta, Canada are the largest natural bitumen deposit in the world, containing about 80 percent of the Alberta total. Ten percent of these deposits, or approximately 170 billion barrels, are considered to be economically recoverable with modern unconventional oil production technology, making Canada's total proven reserves the third largest in the world, after Saudi Arabia's conventional oil and Venezuela's Orinoco oil sands. In 1967, the first large scale commercial operation began with the Sun Oil Company of Ohio opening the Great Canadian Oil Sands mine. As a result, Canada is now, by far, the largest exporter of oil to the United States (U.S.).

This report investigated the current open literature on the nodes and modes of the movement of diluted bitumen (Dilbit) and other associated crude oils to determine potential risks and gaps for response options. It will be used by CG and partner agency decision makers and stakeholders to prioritize research and development efforts; and by the CG R&D Center (RDC) to develop future research plans, based on those priorities.

The scope of this report is to perform and document a qualitative assessment of potential risk of oil sands product (OSP) spills, specifically diluted bitumen (Dilbit); and to identify initial response issues that need to be studied. In addition, this report provides recommendations and proposes research tasks. Specific focus areas of this study are as follows:

- Current and potential routes and nodes of transportation, especially in the Great Lakes, Washington State, and on or near navigable waters that are subject to U.S. Coast Guard (USCG) jurisdiction (in order of priority).
- Geographic areas most at risk of an OSP spill, based upon volume of product transported, location of transportation routes and nodes, and infrastructure condition.
- Response issues related to both fresh water and salt water spills in different seasonal weather conditions and the likelihood that Dilbit would float, sink, or suspend if spilled.

Dilbit Spill Response

Dilbit Behavior. Effective spill response depends on a good scientific understanding of petroleum product behavior in the environment (e.g., movement and changes in physical properties and chemical composition of the oil). There are 12 to 13 types of OSPs, which differ slightly in their reactions in the environment, based on their specific properties.

The four major factors that have a bearing on whether spilled oil, including Dilbit; will float, become neutrally buoyant (suspended in the water column), or sink are as follows:

- Density of the oil, which may change with weathering (evaporation) and emulsification.
- Salinity of the water (i.e., density of the water relative to the oil).
- Amount of sediment in the water.
- Turbidity of the water (stirring up sediment and breaking oil into smaller droplets).

Equipment. In the initial stages of an OSP spill, the responders need typical surface response equipment and tactics. However, it is also essential that the Responsible Party immediately advise the first responders and response contractors; as well as notify the regulatory authorities, that the materials released are OSPs. This information will make all parties aware of the submergence potential of the released materials, so they may select appropriate recovery tactics and associated equipment. A National Oceanographic and Atmospheric Administration (NOAA) study confirmed the previous work done a few years earlier by RDC that multi-beam and imaging sonars are the most effective technologies for conducting wide area detection surveys and searching for large pools of subsurface oil (NOAA, 2013).

Techniques and Tactics. While the most effective approaches to mitigating risk are to prevent accidental spills from occurring in the first place, the next tier of risk mitigation comes from effective response to incidents to reduce the consequences or impacts of an event. Spills from crude oil trains, tank vessels, pipelines, or facilities would require appropriate responses to limit the volume of oil released; reduce the spread of the oil; protect the most sensitive resources as prioritized by geographic response plans and other means; and clean up oil that is released to the environment.

Risk Assessment

Geographic Areas at Risk. The U.S. Department of Energy divides the U.S into five regions for planning purposes. Each region is called a Petroleum Administration for Defense District (PADD). The largest volume of Bitumen & Blended Bitumen exported to the United States is destined for the Midwest PADD 2, Great Lakes region. Although not as significant in volume as the Midwest; PADD 5, the West Coast, saw a 242 percent increase in OSP destinations in 2014 from 2009 levels. The total volumes of Bitumen being exported from Canada to the United States in 2014 is a 76 percent increase from what was exported in 2009. By evaluating the origin of OSP and their eventual destinations in the United States, it is clear that every geographic area of the United States has the potential risk of an OSP spill incident; primarily arising from pipelines and rail during shipment, and eventually from bulk storage facilities and refineries.

Historically, pipelines have been the preferred mode for transporting petroleum products. More oil is transported through the Great Lakes-St. Lawrence River basin by pipeline than by any other mode. Approximately 70 percent of oil sands produced in Alberta ships to U.S. refineries via pipeline. Pipelines are, on average, $5 to $10 per barrel cheaper than rail.

Most concerns over waterborne transportation of crude oil on the Great Lakes relate to the risk of spills from vessels. Oil from oil sands may sink easier in fresh water rather than float on the surface, significantly complicating cleanup actions. There has been recovery of oil on the bottom; but the technology is not packaged and ready to go quickly for an emergency. Existing Vessel Response Plans do not address this type of scenario.

Health Risks. In recent years, Dilbit spills in Michigan, Arkansas, and elsewhere provided convincing evidence on the subject of health risks. Researchers are still working on definitive scientific studies that would translate those examples into broader conclusions about the risks of Dilbit. For example, after the Dilbit entered into the Kalamazoo River in Michigan, it began separating into its constituent parts. The denser bitumen sank to the river bottom. Meanwhile, the chemical additives/diluents evaporated, creating a foul smell that lingered for days. People reported headaches, dizziness, and nausea; and responders were unsure what they should do. Federal officials at the scene did not know until weeks later that the pipeline was carrying Dilbit. Current Federal law does not require pipeline operators to reveal that information.

Benzene, a known carcinogen, is a component of all crude oils and is often a component of the diluent in Dilbit; and could pose a risk to spill responders.

Environmental Risks. In estimating potential environmental impacts of oil spills, several factors are important—including the size and location of the release, leak, or spill; and how quickly it is remediated. The potential for oil to reach water depends on factors such as its proximity to a water source and the characteristics of the environment into which the crude oil is released (e.g., porous underlying soils), the volume of the spill, its duration, and the viscosity and density of the crude oil involved.

The denser components of a Dilbit spill would be difficult to remove from the soil during cleanup operations, and may require soil excavation instead of other remediation techniques. During the Kalamazoo River spill in Michigan in 2010, removal of the denser components from vegetation alongside the river bank was extremely difficult; thus, remediation consisted of removing the contaminated vegetation as well. The ultimate extent, shape, and composition of a groundwater contaminant plume resulting from a Dilbit spill depends on the specific characteristics of the soil, aquifer, and the amount and duration of the accidental release.

Proposed Research Tasks

Section 5 details the proposed research tasks that can be prioritized by both Coast Guard and partner agency stakeholders/decision makers. Addressing these research topics will provide the Federal On Scene Coordinator (FOSC) tools to enhance managing a response to these type spills. In general, the RDC is equipped to research and develop technologies related to detecting, tracking, containing, recovering, and decanting oil spills. The RDC is also positioned to assist in developing FOSC guidance for these types of oil spills:

Technology/Tools Development

1) Modeling and Prediction – develop modeling tools to predict submerged oil transport/trajectories on short and long term time scales.
2) Containment – develop techniques for barriers on the bottom.
3) Recovery – identify or develop pumps that can be used for OSPs.
4) Decanting – determine methods to optimize the decanting process.
5) Detection – identify better methods to locate and map oil when submerged, especially when mixed with silt.
6) Chemical Countermeasures – identify techniques and windows of opportunity for using dispersants.

Information Development

1) Water Intake Systems – develop guidelines for protection and treatment methods.
2) Submerged Oil Guidance – develop guidance for use in plans.
3) American Petroleum Institute (API) Publication Review – review API publications dealing with fresh water to include additional guidance.
4) Decision Making – develop protocols to assess potential impacts to assist decision-making.
5) Dilbit Behavior – develop models or decision tools based on behavior and toxicity.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	Association of American Railroads
AB	Alberta, Canada
ACP	Area Contingency Plan
AMOP	Arctic and Marine Oilspill Program
ANPRM	Advance Notice of Proposed Rulemaking
ANS	Alaskan North Slope
AOPL	Association of Oil Pipelines
API	American Petroleum Institute
ATSDR	Agency for Toxic Substances and Disease Registry
bbl	Barrels
bbl/d	Barrels per day
BMWED	Brotherhood of Maintenance of Way Employees Division
BNSF	Burlington Northern Santa Fe
BTEX	Benzene, Toluene, Ethyl Benzene, and Xylene
CA	Canada
CAPP	Canadian Association of Petroleum Producers
CCQTA	Canadian Crude Quality Testing Association
CCR	California Code of Regulations
CEPA	Canadian Energy Pipelines Association
CFR	Code of Federal Regulations
CN	Canadian National Railway
CNEB	Canadian National Energy Board
CO	Colorado
CO2	Carbon Dioxide
COOGER	Centre for Offshore Oil, Gas and Energy Research [Canada]
CP	Canadian Pacific
CPC	Casualty Prevention Circular
CRS	Congressional Research Service
CSS	Cyclic Steam Stimulation
CT	Connecticut
DE	Delaware
DFO	Department of Fisheries and Oceans [Canada]
DHHS	Department of Health and Human Services
Dilbit	Diluted Bitumen
DMPS	Dynamic Motion and Position Sensor
DOT	Department of Transportation
ECP	Electronically Controlled Pneumatic
EEZ	Exclusive Economic Zone
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERC	Environmental Research Consulting

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

ESTD	Environment Canada, Emergencies Science and Technology Division
FOSC	Federal On-Scene Coordinator / Federal On-Scene Commander
FRA	Federal Railroad Administration
GAO	Government Accountability Office
GC	Gas Chromatography
GFI	Government Furnished Information
GIUE	Government Initiated Unannounced Exercise
GOM	Gulf of Mexico
GPS	Global Positioning System
GRP	Geographic Response Plan
H2S	Hydrogen Sulfide
HHFT	High-Hazard Flammable Train
HLPSA	Hazardous Liquid Pipeline Safety Act
IFO	Intermediate Fuel Oil
IMDG	International Maritime Dangerous Goods [United Nations]
IMDS	Ion Mobility Drift Spectrometry
IMT	Incident Management Team
IOSC	International Oil Spill Conference
IR	Infrared
IRS	Internal Revenue Service
ISCO	International Spill Control Organization
LA	Louisiana
LDS	Leak Detection Systems
LHG	Liquefied Hazardous Gas
LIDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LTO	Light Tight Oil
MCL	Maximum Contaminant Level
MN	Minnesota
MPC	Marine Pollution Control
MSDS	Material Safety Data Sheet
MT	Montana
MTR	Marine Transportation-Related
NCP	National Contingency Plan
NDT	Non-Destructive Testing
NEB	National Energy Board
NGL	Natural Gas Liquid
NJ	New Jersey
NM	New Mexico
NOAA	National Oceanographic and Atmospheric Administration
NPC	National Petroleum Council

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NPREP	National Preparedness For Response Exercise Program
NPRM	Notice of Public Rulemaking
NRC	National Research Council
NRC	National Response Center
NRDC	Natural Resources Defense Council
NRT	National Response Team
NTSB	National Transportation Safety Board
NW	North West
NWAC	Northwest Area Committee
NWACP	Northwest Area Contingency Plan
O&M	Operations and Maintenance
OK	Oklahoma
OMA	Oil-Mineral Aggregates
OPA	Oil Pollution Act
OPEC	Organization of Petroleum Export Countries
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-Operation, 1990 (Maritime Law)
OPS	Office of Pipeline Safety
OSHA	Occupational Safety & Health Administration
OSLTF	Oil Spill Liability Trust Fund
OSP	Oil Sands Product
OSPR	Office of Spill Prevention & Response [California Department of Fish and Game]
OSRO	Oil Spill Response Organization
OSRP	Oil Spill Response Plans
PA	Pennsylvania
PADD	Petroleum Administration for Defense District
PHMSA	Pipeline and Hazardous Materials Safety Administration
PPE	Personal Protective Equipment
ppm	parts per million
PREP	Preparedness For Response Exercise Program
R&D	Research and Development
ROV	Remotely-Operated Vehicle
RRT	Regional Response Team
SAGD	Steam Assisted Gravity Drainage
SAM	Staffing Allocation Model
SCO	Synthetic Crude Oil
SG	Specific Gravity
TSB	Transportation Safety Board
TX	Texas
U.S.	United States

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

UP	Union Pacific
URL	Uniform Resource Locator (a.k.a. Universal Resource Locator)
US	United States
USA	United States of America
USCG	United States Coast Guard
USDOI	United States Department of Interior
USGC	United States Gulf Coast
USGS	United States Geological Survey
UT	Utah
UV	Ultraviolet
VP	Vice President
VRP	Vessel Response Plan
V-SORS	Vessel-Submerged Oil Recovery System
VTS	Vessel Traffic Systems
WA	Washington
WCMRC	West Canada Marine Response Corporation
WCSB	Western Canada Sedimentary Basin
WEC	World Energy Council
WHMIS	Workplace Hazardous Materials Information System
WSA	Waterway Suitability Assessment

1 INTRODUCTION

1.1 Purpose

This report investigated the current open literature on the nodes and modes of the movement of diluted bitumen (Dilbit) and other associated crude oils to determine potential risks and gaps for response options. It will be used by CG and partner agency decision makers and stakeholders to prioritize research and development efforts; and by the CG R&D Center to develop future research plans, based on those priorities.

1.2 Background

Domestic production of crude oil in North America has increased at a tremendous rate. This increased production is predicted to continue into the future, creating significant challenges in transporting crude oil to domestic markets, especially to refineries. The forecasted output for 2015 represents what will be the highest level of domestic production in the U.S. since 1972; 9.3 million barrels per day (bbl/d), a 75 percent increase over 2009 levels (Short Term Energy Outlook, 2014).

Crude oil can be categorized into conventional and unconventional crude oil. Conventional oil is a category that includes crude oil, natural gas, and its' condensates. Conventional crude oil is typically produced by drilling into an oil reservoir to extract the crude oil. Initially, natural reservoir pressure forces the oil to the surface, which becomes the primary production method. Natural pressure in most reservoirs eventually dissipates, requiring secondary production methods to extract the oil. Secondary production methods include installing a pump in the well or injecting gas into the liquid some distance down the well to decrease the weight of the hydrostatic column. Eventually tertiary or enhanced oil recovery methods may be needed to increase the oil's flow characteristics; i.e., injecting steam, carbon dioxide, and other gases or chemicals into the reservoir. In the United States, primary production methods account for less than 40 percent of the oil produced on a daily basis; secondary methods account for approximately half; tertiary recovery accounts for the remaining 10 percent.

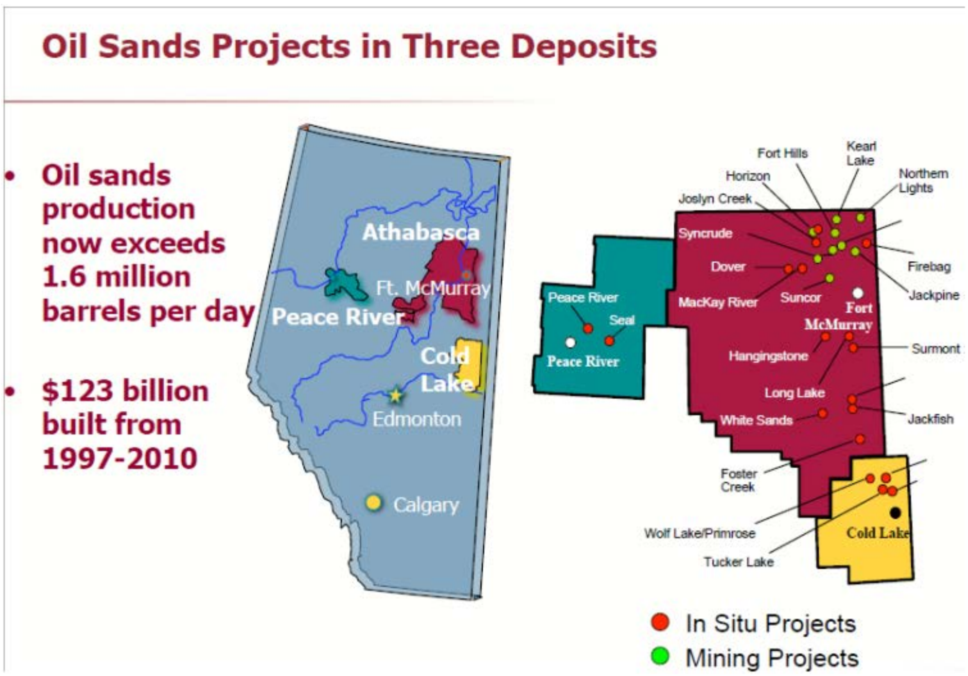
Unconventional oil consists of a wider variety of liquid sources, including oil sands, extra heavy oil, gas to liquids, coal to liquids, and kerogen oil. Unconventional crude oil includes Oil Sands Products (OSP) produced in Alberta, Canada; and shale oil produced in various areas of the United States. Oil sands generally consist of extra heavy crude oil or crude bitumen trapped in unconsolidated sandstone. Bitumen is extremely dense and viscous, with a consistency ranging from that of molasses for some extra-heavy oil to solid as peanut butter for some bitumen at room temperature, making extraction difficult. Bitumen has a density (specific gravity) approaching or even exceeding the density of water. As a result of their high viscosity, bitumen cannot be produced by conventional methods; transported without heating or dilution with lighter hydrocarbons (diluents); or refined by older oil refineries without major modifications. Diluted bitumen (Dilbit) is typically comprised of 70 percent bitumen and 30 percent diluent.

1.3 Locations and Proven Oil Reserves

According to the U.S. Energy Information Agency (EIA), North Dakota's Bakken and Texas' Permian Basin and Eagle Ford Shale generate at least a third of total U.S. daily oil production (Javier, 2014). The dramatic increase in oil production since 2008 was enabled by applying horizontal drilling and hydraulic fracturing, the techniques developed to produce shale gas.

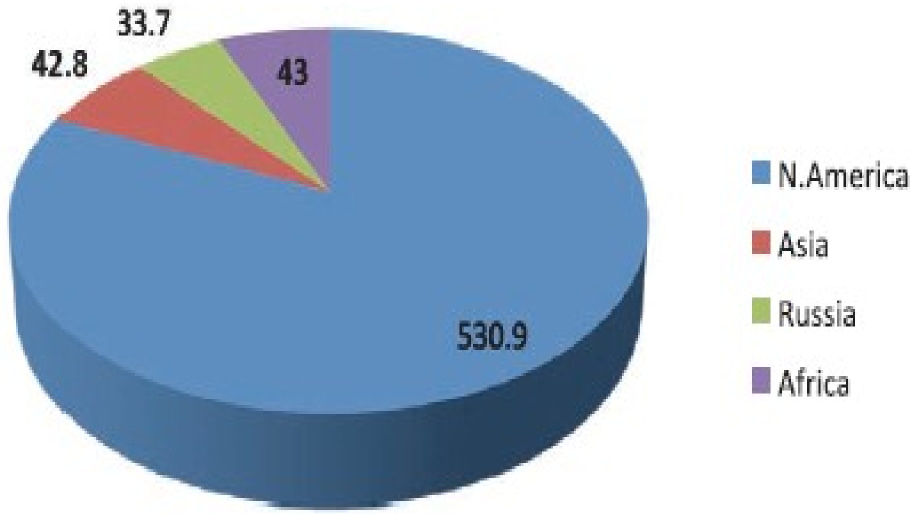
The Alberta government estimates that, with current technology, ten percent of its bitumen and heavy oil can be recovered; which translates to approximately 200 billion barrels of recoverable oil reserves. In 1967, the first large scale commercial operation began with the opening of the Great Canadian Oil Sands mine by the Sun Oil Company of Ohio. Today its successor company, Suncor Energy (no longer affiliated with Sun Oil), is the largest oil company in Canada. In addition, other companies, such as Royal Dutch Shell, ExxonMobil, and various national oil companies are developing the Athabasca oil sands. As a result, Canada is now, by far, the largest exporter of oil to the United States.

The largest Canadian oil sands deposit, the Athabasca oil sands in the McMurray Formation, is centered on the city of Fort McMurray, Alberta. (See Figure 1) The Athabasca oil sands lie along the Athabasca River; and are the largest natural bitumen deposit in the world, containing approximately 80 percent of the Alberta total, and the only one suitable for surface mining. Ten percent of these deposits, or approximately 170 billion barrels, are considered to be economically recoverable with modern unconventional oil production technology; making Canada's total proven reserves the third largest in the world, after Saudi Arabia's conventional oil and Venezuela's Orinoco oil sands. (See Figure 2)



Source: (National Academy of Science, 2012)

Figure 1. Map of oil sands projects in three deposits.



Source: (Chopra, Lines, Schmitt, & Batzle, 2010)

Figure 2. Bitumen reserves by regions.

Athabasca sands contain very large amounts of bitumen covered by little overburden, making surface mining the most efficient method of extraction. The overburden consists of water-laden muskeg (peat bog) over top of clay and barren sand. The oil sands themselves typically are 40 to 60 meters thick, with deposits of crude bitumen embedded in unconsolidated sandstone, sitting on top of flat limestone rock. More details of recovery methods are contained in Appendix A.

The Bakken formation emerged in recent years as one of the most important sources of new oil production in the United States. Most Bakken drilling and production is in North Dakota, although the formation also extends into Montana and the Canadian provinces of Saskatchewan and Manitoba. As of 2013, the Bakken formation was the source of more than ten percent of all U.S. oil production. As a result of increased production from the Bakken formation and long-term production declines in Alaska and California, North Dakota (as of 2014) was the second largest oil-producing state in the United States in volume of oil produced; Texas is the largest.

The Eagle Ford is the second-most productive field in the United States, yielding more than 1.6 million bbl/d of oil, compared with 1.8 million bbl/d in the Permian Basin and approximately 1.2 million bbl/d in North Dakota's Bakken field. The EIA expects production at the Eagle Ford to top 1.7 million bbl/d by the end of February 2015 (Ausick, 2015).

1.4 Growing Transportation Needs

The acceleration in crude oil production challenges both industry and government to address the growing need to transport crude oil efficiently, safely, and economically from the oil fields to refineries and points of export. Crude oil transportation modes include pipelines (the oil industry's traditional preferred mode of transporting petroleum products) and oceangoing tankers. Currently, more producers are turning to rail transport and other methods to transport crude oil as a result of capacity bottlenecks in the pipeline network.

Based on data from Genscape, Oil Change International estimates that, on average, around 100,000 to 150,000 barrels of Dilbit load at terminals in Alberta every day. The oil shipments by train take, on average, nine days to reach its destination; therefore, at any given time, between 18 and 27 trains carrying Dilbit through North America are loaded with some 0.9 to 1.4 million barrels (Rowell, 2015). In addition to Dilbit, approximately one million bbl/d of light, tight crude oil is transported in North America.

The importance of issues surrounding the safety of oil transportation in North America via pipeline and railroad was underscored by two particularly significant incidents:

1. In July 2010, an oil spill occurred in the Great Lakes-St. Lawrence River region when a pipeline carrying Dilbit from the Alberta oil sands spilled into Talmadge Creek, a tributary of the Kalamazoo River, near Marshall, Michigan. Approximately one million gallons of oil was spilled, resulting in one of the largest inland spills and cleanups in U.S. history.
2. On July 6, 2013, a train carrying numerous tank cars of Bakken crude oil derailed in the town of Lac-Mégantic, Québec. The derailment resulted in an explosion, causing the loss of 47 lives, hundreds of millions of dollars of damage to the town, and a spill of Bakken crude oil in the Chaudière River, the main source of drinking water for thousands of citizens downstream.

These two incidents generated regional and binational interest regarding the safety of transporting Dilbit and Bakken crude oil via pipeline and rail; the age of the infrastructure; and the need to review and evaluate the programmatic and regulatory framework to ensure the transportation of oil is safe.

1.5 Scope

The scope of this project and report is to perform and document a qualitative assessment of potential risk of OSP spills, particularly Dilbit spills, and identify initial response issues that need to be studied. OSP and Dilbit in particular are subject to spilling during transport from the source in Alberta, Canada, via pipeline, tank cars, or marine vessels, such as barges and coastal tankers. Truck transport of Dilbit on the highways is not within the scope of this study; because very little oil is transported this way. Since the transport of Dilbit uses the same infrastructure that transports other conventional and unconventional crude oils; this study provides information regarding these petroleum products. The focus of this study is on Dilbit and the associated risk of transporting Dilbit.

Dilbit is transported because the source in Alberta, Canada, is far removed from the refineries in the U.S. The pipelines and railroads that carry Dilbit pass through nearly every state in the continental U.S.; are in close proximity to navigable waterways, such as the Great Lakes and Western Rivers; and transit areas that include fresh water aquifers and large metropolitan areas that are densely populated. Therefore, the scope of this study involves an assessment of the risks to the environment and public safety.

Dilbit spills are inevitable, given the quantity being transported on a daily basis and the age and material condition of the transportation infrastructure, as well as the potential for operating errors. Spills are often in remote areas and locations far removed from first responders. Dilbit contains volatile substances that may lead to explosion and fire in catastrophic spills. In addition, Dilbit does not behave exactly like crude oil and has the potential to submerge beneath the surface; if spilled into water under the right conditions. The scope of this study includes identifying the response issues for responders and appropriate recommendations for consideration by the United States Coast Guard (USCG).

Specific focus areas of this study include:

- Current and potential routes and nodes of transportation; especially in the Great Lakes, Washington State, and on or near navigable waters subject to USCG jurisdiction (in order of priority).
- Geographic areas most at risk of an OSP spill; based upon volume of product transported, location of transportation routes and nodes, and infrastructure condition. Details concerning the proven reserves, transportation modes (pipelines, rail, and vessels), as well as risks of transporting crude oil due to aging and material condition of the pipeline and rail infrastructure are contained in Appendix B.
- Response issues related to both fresh and salt water spills in different seasonal weather conditions; and the likelihood that Dilbit would float, sink, or suspend if spilled.

1.6 Technical Approach

The approach to the conduct of this study involved a thorough review of Government Furnished Information (GFI) (See Section 6); a limited literature review of open sources (See Section 7); and documentation of findings in this report. The goal of the GFI review and literature search was to collect information in order to perform the qualitative risk assessment of potential spills of Dilbit and to identify initial response issues. Specifically, the following information along with appropriate recommendations, is documented in the specified sections in this report:

- Techniques identified for response to surface oil and submerged oil spills that can address OSPs.
- Geographic areas most at risk for spills and the prime routes of transportation in those areas.
- Identification of rail transportation, pipeline, health and environmental risks.
- Identification of what additional information is needed by USCG decision-makers; what additional equipment or tactics are needed by responders to prepare for Dilbit spills in waterways grouped by offshore spills and near-shore/on-shore spills; and how addressing these recommendations will provide more robust and safer response to future spills of Dilbit.
- A description of proposed tasks for future research efforts related to each recommendation.

2 DILBIT SPILL RESPONSE

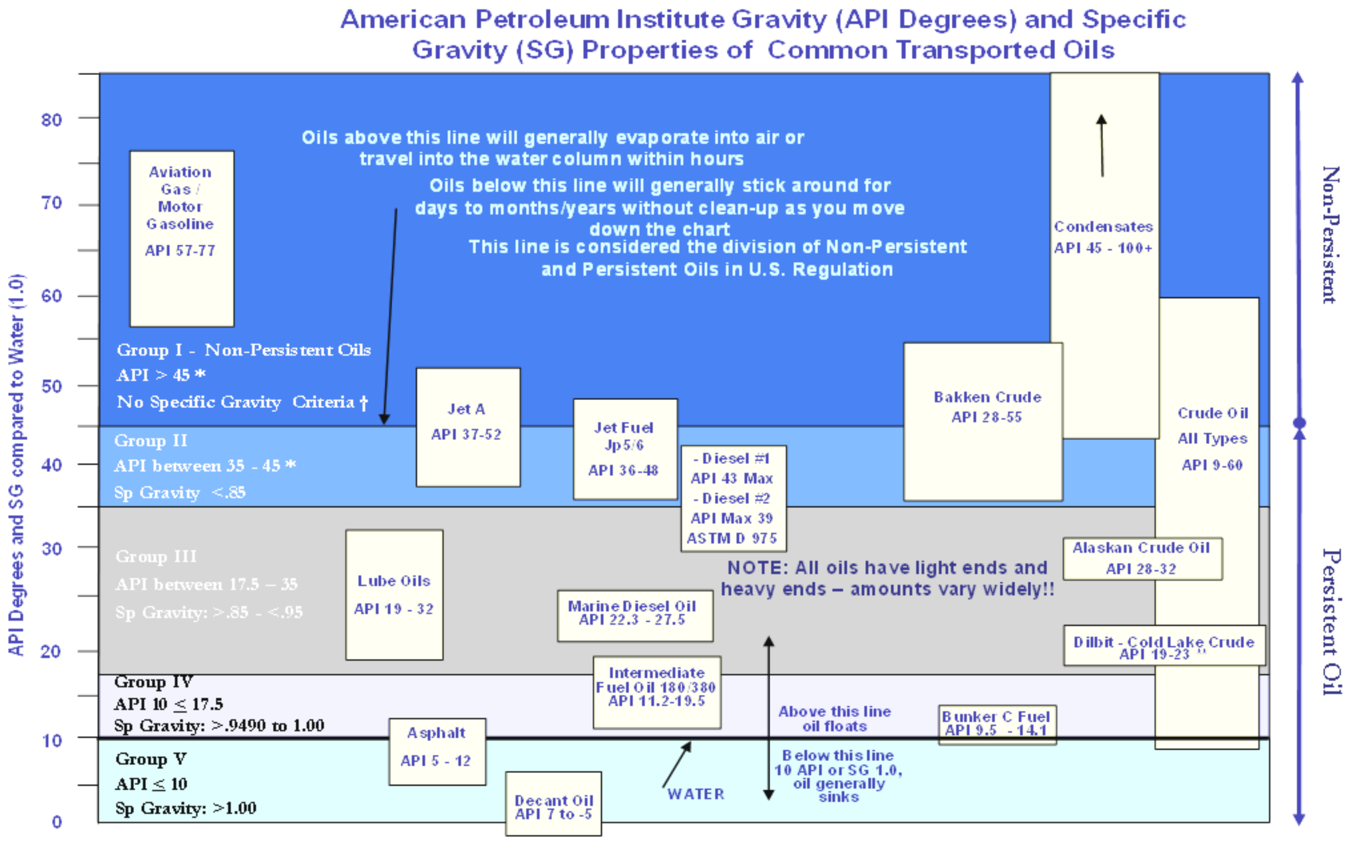
Four significant pipeline spills of Dilbit have occurred in the United States and Canada (NOAA, 2013). The pipeline incidents include spills from Enbridge pipelines in Michigan and Illinois; a Kinder Morgan Canada pipeline spill in Burnaby, B.C.; and one spill at a TransCanada-operated Keystone Pipeline pump station in North Dakota. The most recent spill was a pipeline failure in the ExxonMobil Pegasus line in Mayflower, Arkansas; which released a significant amount of Dilbit into a suburban residential neighborhood. (See Appendix C for additional details regarding these Dilbit spills.)

In a 2015 Railway Age article concerning the February 16, 2015, derailment and fire of a Canadian National Railway unit train in Ontario; it was noted that the railroad train carried Dilbit, which as noted before, is generally thought to be less explosive than Bakken crude. It is not clear if the lighter components of the Diluent contributed to the fire (Thomas, 2015). Canada's Transportation Safety Board (TSB) can be expected to analyze the Dilbit lading of CN's Ontario accident, as it did the Bakken crude that exploded at Lac-Mégantic in 2013. TSB reported then that Bakken crude is more volatile than other varieties. Should TSB conclude that Dilbit has a volatility similar to Bakken crude, as the Alberta research suggests, the hazmat classification of crude oil could be in question.

2.1 Dilbit Behavior

Effective spill response depends on a good scientific understanding of petroleum product behavior in the environment (e.g., movement and changes in physical properties and chemical composition of the oil). For example, in calm waters, booms can help contain floating oil spills and make skimmer recovery equipment more effective; so it is important to know what fraction of the oil will float or sink and under what conditions. There are 12 to 13 types of OSPs; they differ slightly in how each reacts in the environment based on their specific properties. According to laboratory and mesoscale weathering experiments, Dilbit products have physical properties much aligned with a range of intermediate fuel oils and other heavy crude oils. Environment Canada (2013), the US EPA and others have been performing research in the behavior of dilbit. More details can be found in Appendix C.

The oil industry classifies different crude oils as light, medium, or heavy; based on their densities. There is debate over the density cutoffs for these categories, but bitumen falls into the extra heavy category because it is denser than water. The Dilbit that spilled from the Enbridge Line 6B in Kalamazoo, Michigan, was less dense than water and considered heavy crude oil. Density alone does not determine whether a particular type of crude oil will sink or float. Weather and other conditions can change the buoyancy of crude oils; for example, crudes that are less dense than water can sink if they mix with sediment. In general, the density of bitumen ranges from slightly denser than water to barely less dense than water. Figure 3 shows the density of common transported oils. This figure uses the California OSPR definition for the Group I/II boundary.



**Dilbit generally contains percentage of products heavier than water.
†Group I oils determined by distillation criteria that one cannot easily use in field. Group II unbounded on light ends except Group I definition (33 CFR 155.1020). Note: California set lower boundary for pre-booming Group II oils at 45°API gravity. All else same as 33 CFR 155.1020. Salt water specific gravity (SG) 1.025(+/– depending on locality).
†33 CFR 1020 Definitions: Non-persistent/Group I oil means petroleum-based oil that, at time of shipment, consists of hydrocarbon fractions: (1) At least 50 percent of which by volume, distill at 645°F; and (2) At least 95 percent of which by volume, distill at a temperature of 700°F

Source: (Washington State Dept. of Ecology, 2015)

Figure 3. Density of common transported oils.

2.2 Major Factors in Spilled Oil Behavior

The four major factors that have a bearing on whether spilled oil, including Dilbit, will float, become neutrally buoyant (suspended in the water column), or sink are:

- Density of the oil, which may change with weathering (evaporation);
- Turbidity of the water (stirring up sediment and breaking oil into smaller droplets);
- Salinity of the water (i.e., density of the water relative to the oil); and
- Amount of sediment in the water.

2.2.1 Density and Turbidity

The Washington State Marine and Rail Study continues to provide the guidance that, as long as the oil is less dense than the water, it will float (Washington State Dept. of Ecology, 2015). It may temporarily become submerged in the water column if broken into smaller droplets in turbulent water but, in those cases, it will refloat under calmer water conditions. If the oil becomes denser than the water, either by becoming

attached to sediment particles, or, less commonly, by having enough of the lighter components evaporate to increase the density, it will become neutrally buoyant or sink.

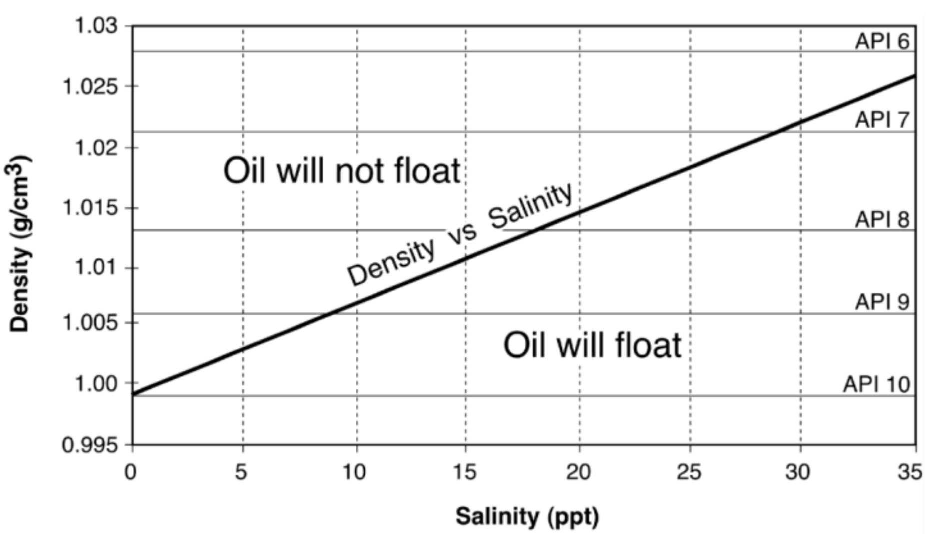
2.2.2 Salinity

Since salt and brackish water (e.g., water in estuaries) is heavier than freshwater, it takes a greater increase in density to cause oil to sink in salt or brackish water than in freshwater, where the density of water is 999.97 kg/m^3, or essentially 1,000 kg/m^3 or 1.0 g/ml. Seawater is denser than freshwater and has an average density of 1.025 g/ml, though it may be as high as 1.028 g/ml. Brackish water in estuaries varies in density between 1.0 to 1.025 g/ml. For this reason, heavy oil with a density of 1.01 g/ml would float in seawater but sink in a freshwater lake, or in an estuary (see Figure 4).

A study was conducted comparing the density of Dilbit as a function of temperature and salinity to identify conditions where the Dilbit would sink (Short, 2013). These results were then compared with environmental conditions from Kitimat, British Columbia, to the outer coast to show that at least some of the Dilbit would be expected to sink in fresh water and in brackish water less than 24 hours after an accidental discharge.

Freshwater spills may entail fast flowing and turbulent waterways (e.g., creeks, rivers) that, with the less buoyancy of fresh water, may add to the evaporation of the diluents and the mixing of the bitumen with sediments and thus contribute to a portion of the spilled material submerging below the surface in the water column or pooling on the bottom.

Notwithstanding the general differences between Fresh and Saltwater environments, the general principles of responding to submerged oil spills remain the same for salt water environments as they do for freshwater environments.



Source: (Michel, Ploen, & Elliot, 2014)

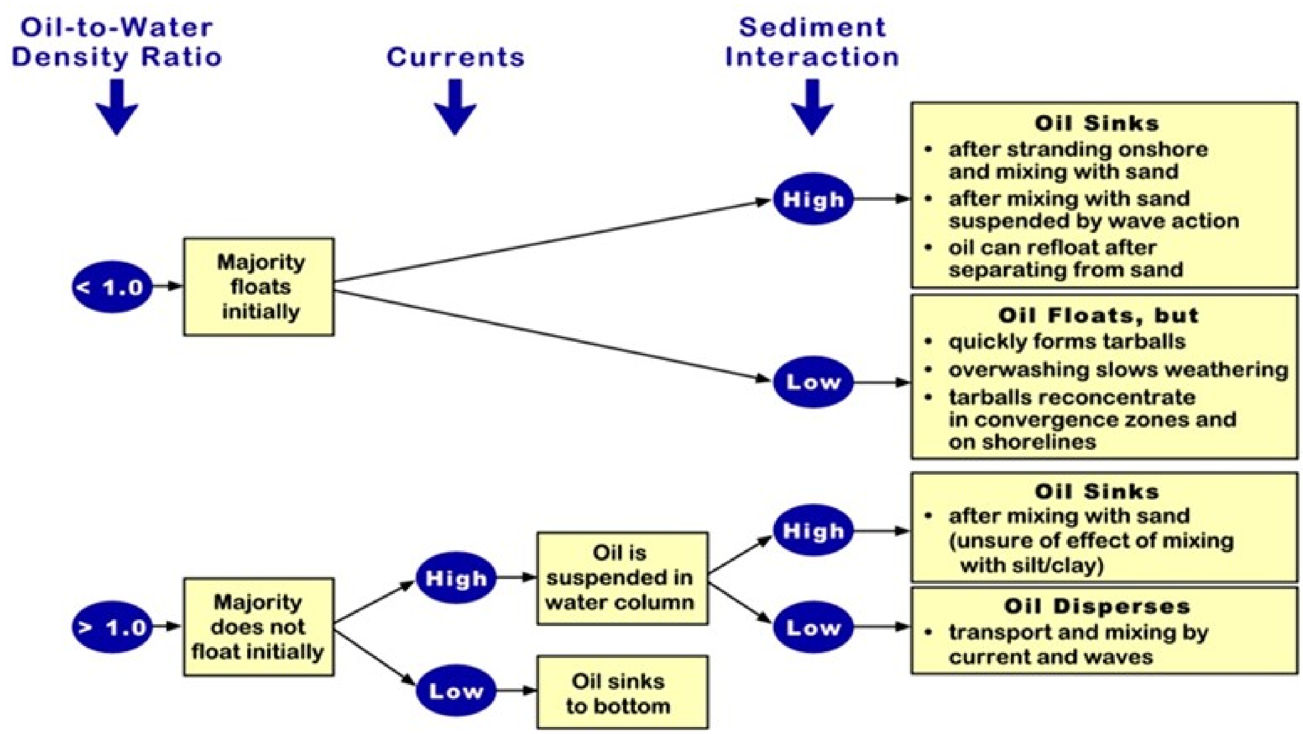
Figure 4. Density vs. salinity.

2.2.3 Amount of Sediment in Water

When oil mixes with sediment particles (e.g., sand in the surf zone of a beach), the combinations of sediment and oil, called oil-mineral aggregates (OMAs), can become heavier than water and cause sinking. OMA formation is more likely to occur in the following situations:

- The oil is in fine droplets;
- There is a large sediment load in the water column; and
- There is a lot of turbulence in the water, which increases the number of smaller oil droplets, stirs up sediment from the bottom, and increases the likelihood of contact between the oil droplets and sediment particles.

OMA sinking is more likely to occur in freshwater than salt or brackish water because of the greater likelihood that the density of the OMA will be higher than the water density. The OMA density has to be somewhat higher to sink in salt or brackish water. The following figure shows the behavior of spills of Group V oils.

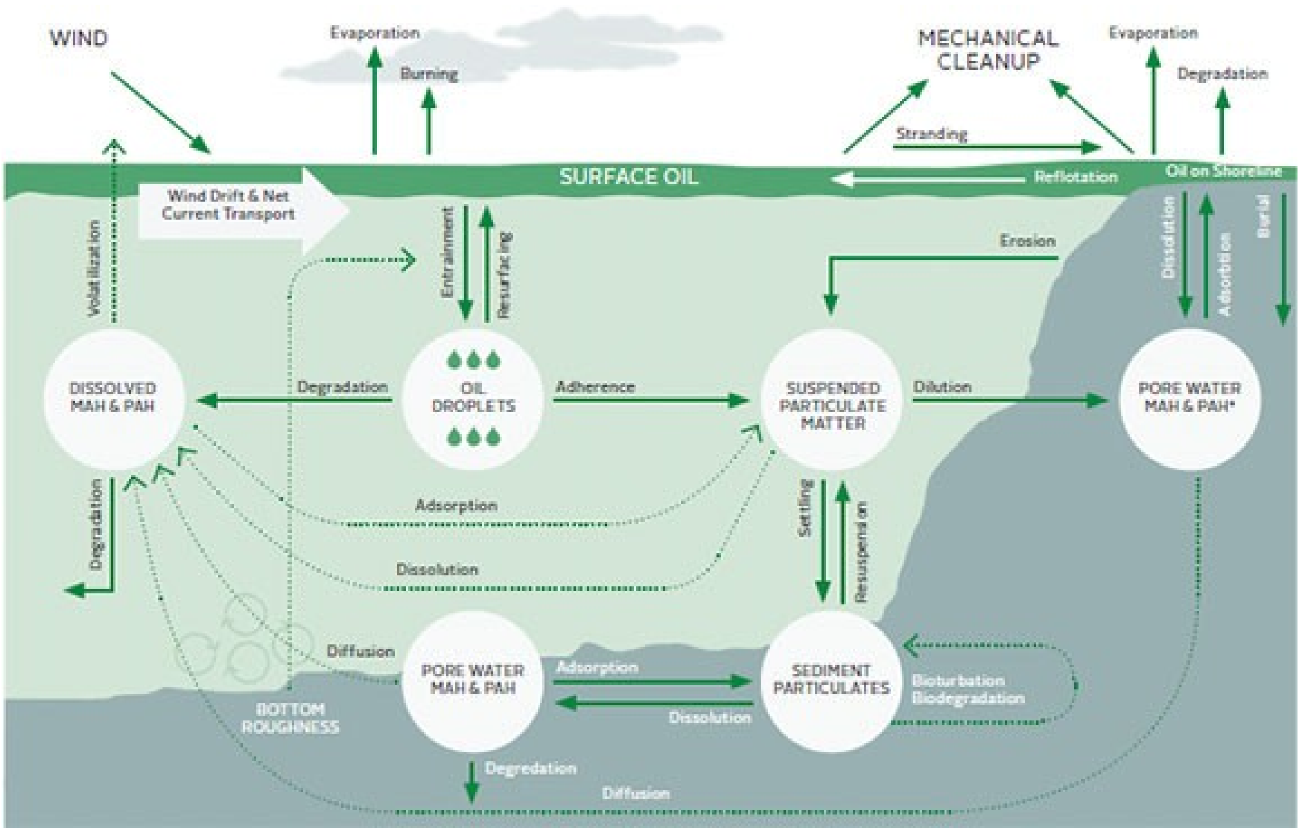


Source: (Michel, Ploen, & Elliot, 2014)

Figure 5. Behavior of spills of Group V oils.

2.2.4 Dilbit Spills in Freshwater and Estuarine Systems

If Dilbit were to spill into a freshwater or an estuarine system, as would occur in inland areas, it would undergo the processes shown in the following figure (Washington State Dept. of Ecology, 2015).



Source: Enbridge Northern Gateway Project Joint Review Panel.

Figure 6. Processes that Dilbit undergoes as a result of a spill in a fresh water system.

Given that there may be sediment in the freshwater river, stream, or lake, it is possible for the Dilbit to create OMAs and sink. This situation would be most likely in a shallower stream with a rapid current, high sediment load, and turbulent waters that stir up the bottom sediment and break the oil into smaller droplets.

In saltwater, the oil would undergo similar processes, but it is less likely that the oil would sink due to the salinity of the water causing an increase in the density of the water. If oil sinks below the surface of the water, it becomes much harder to detect and recover.

2.2.5 Effects of Evaporation

Theoretically, if enough of the light ends of an oil evaporate, the overall density of the oil would increase, perhaps enough to cause the density to be more than that of freshwater or even saltwater. When spilled into water, lighter hydrocarbon fractions of the entire Dilbit blend begin to evaporate. As lighter fractions evaporate, the viscosity of the weathered Dilbit would increase, and evaporation of remaining lighter fractions would be progressively inhibited.

Other heavy oils typically have minimal light components. Therefore, evaporation occurs differently for Dilbit compared to other heavy oils. Environment Canada confirmed this to be the case in its 2013 Technical Report (Environment Canada, ESTD; DFO; & COOGER, 2013). Approximately four to five times as much of the Dilbit evaporated compared to intermediate fuel oil (a heavy oil with no diluent), and the evaporation occurred much faster for Dilbit than for intermediate fuel oil in their study. Evaporation

transports toxic components of the Dilbit into the air, creating a short-term exposure hazard for spill responders and assessment scientists at the site of the spill, which was the case at the 2010 Enbridge spill.

Since the light ends (low density components) of the oil evaporate after Dilbit spills, the leftover residue is even denser than what was spilled initially. Studies, produced by Environment Canada, Witt|O'Brien's, Polaris, and West Canada Marine Response Corporation (WCMRC), and SL Ross Environmental Research Limited measured the increase in Dilbit density over time as it weathered; their findings are that Dilbit density increased over time and eventually reached approximately the same density as freshwater (Environment Canada, ESTD; DFO; & COOGER, 2013) (Witt|O'Brian's, Polaris, & WCMRC, 2013) (SL Ross Environmental Research Limited, 2012).

A NOAA study conducted an analysis which was based on the assumption that OSPs will remain on the surface for several hours or days when spilled into saltwater, but as sedimentation and volatilization occurs, some of the oil will submerge or sink (NOAA, 2013). This assumption was supported by Enbridge technical data reports released in conjunction with the proposed Northern Gateway pipeline project. The reports suggested that in a marine spill scenario, 80 percent of the oil would remain on the surface for 120 hours under summer conditions (i.e., would not easily sink) but "*will be easily over washed with water.*" Due to the lack of available case studies on OSP spills, this analysis evaluated equipment effectiveness in past heavy oil spills, where the oil was submerged in the water column or sank. This theory is relevant to the oil sands discussion, as OSPs may behave like non-floating oils after weathering and other interactions with the environment.

2.2.6 Dilbit Hazards and Risks Different than Other Crudes

The Congressional Research Service report made the observation in the aftermath of a 2010 pipeline spill that is consistent with the assertion that Dilbit may pose different hazards, and possibly different risks, than other forms of crude oil (Frittelli, et al., 2014).

Three years after the spill, response activities continued because, according to EPA, the oil sands crude "*will not appreciably biodegrade*." The Dilbit sank to the river bottom, where it mixed with sediment, and EPA ordered Enbridge to dredge the river to remove the oiled sediment. As a result of this order, Enbridge estimated in September 2013 its response costs would be approximately $1.2 billion, which is substantially higher than the average cost of cleaning up a similar amount of conventional oil.

2.3 Jurisdiction

Understanding the regulatory jurisdictions is important for the CG as some requirements overlap, especially for response plans.

2.3.1 Rail

The Federal Railroad Administration (FRA) has jurisdiction over railroad safety. It has approximately 500 federal inspectors throughout the country and also uses approximately 180 state railroad safety inspectors. State inspectors predominantly enforce federal requirements because federal rail safety law preempts state law and federal law is pervasive. The FRA uses past incident data to determine where to target its inspection activity, although the FRA Administrator stated that, in light of the growth of crude-by-rail transportation, the agency also must look for pockets of risk. FRA regulations cover the safety of track, grade crossings, rail equipment, operating practices, and movement of hazardous materials (hazmat). The Pipeline and

Hazardous Materials Safety Administration (PHMSA) within DOT issues requirements for the safe transport of hazmat by all modes of transportation, which the FRA enforces with respect to railroads.

When a rail incident results in the release of oil, the first government representatives to arrive at the scene are typically state, territorial, or local officials, who initiate immediate safety measures to protect the public. The National Oil and Hazardous Substances Pollution Contingency Plan, e.g., the National Contingency Plan (NCP), indicates that state, territorial, or local officials may be responsible for conducting evacuations of affected populations. First responders notify the National Response Center to elevate an incident for federal involvement, at which point the coordinating framework of the NCP would be applied.

U.S. safety requirements apply to any train operating in the United States, regardless of its origin or destination. Canadian safety regulations are very similar but do not exactly mirror U.S. requirements. Cross-border shipments must meet the requirements of both countries. Safety standards established by the rail industry, which often exceed government requirements, apply to both U.S. and Canadian railroads.

2.3.1.1 *PHMSA Proposed Rules*

The PHMSA has proposed several rules relating to classification, packaging, and testing of mined gases and liquids, including crude oil. The offeror of the cargo, "*must certify that hazardous material is properly classified, described, packaged, marked, and labeled*," and the classification is used to select proper equipment (tank, service equipment, interior lining, or coating). PHMSA has also proposed to define a high-hazard flammable train as a "*single train containing 20 or more tank carloads of Class 3 (flammable liquid) material.*" PHMSA stated that crude oil and ethanol are the "*only known Class 3 (flammable liquid) materials transported in trains consisting of 20 tank cars or more*." The definition of high hazard flammable train thus would not apply to other Class 3 trains consisting of 20 tank cars or more.

Due to the recent rail incident history, PHMSA and the Federal Railroad Administration have issued an Advanced Notice of Proposed Rulemaking on August 1, 2014 concerning oil spill response plans for high-hazard flammable trains, and a Proposed Rulemaking concerning enhanced tank car standards and operational controls for high-hazard flammable trains (PHMSA, 2014a) (PHMSA, 2014b).

2.3.1.1.1 Response Plans

Regulations require that railroads have either a so-called basic response plan or a more comprehensive response plan, depending on the volume capacity of the tank car transporting the oil. Comprehensive plans are subject to FRA approval and must ensure by contract or other means that personnel and equipment are able to handle a worst-case discharge. However, because the regulatory threshold for the comprehensive response plan is a tank car holding more than 1,000 barrels, the regulation does not apply to the DOT-111 tank cars used today, which hold approximately 700 barrels of oil. For these smaller tank cars, railroads must prepare only basic response plans, which are not subject to FRA approval. The current draft of the National Preparedness for Response Exercise Program (PREP) Guidelines (March 2015), Section 2, Guiding Principles, L, Special Considerations, 6, Railroad Tank Cars and Motor Vehicle Tank Trucks includes the statement, "There are few individual railroad tank cars or motor vehicle tank trucks transporting sufficient volumes of oil to be subject to the response planning requirements of OPA 90." (USCG, 2015). Currently this statement may be true; however, that status is due to change and, as such, USCG and EPA as the potential Federal On-Scene Coordinators (FOSCs) of a rail incident, need to be cognizant that railroad Responsible Parties and their response contractors are, at this time, not trained and exercised pursuant to potential new regulatory Comprehensive Response Plan requirements for railcars since the Basic OSRPs do not require training and exercising. This threshold was established in 1996, before the advent of oil unit

trains, each of which may transport, in aggregate, approximately 70,000 barrels (almost three million gallons) of oil. The NTSB recommended that the threshold for comprehensive plans be lowered to account for the use of unit trains. On August 1, 2014, U.S. DOT issued an Advance Notice of Proposed Rulemaking (ANPRM) lowering the threshold (PHMSA, 2014a).

Responses to a rail carrier spill incident are covered by regulations promulgated under the Oil Pollution Act of 1990. However, currently, only tank cars with capacities of 42,000 gallons/1,000 barrels or more are required to have Comprehensive Response Plans. There are currently no rail Comprehensive Response Plans. All rail carriers currently have Basic Response Plans if they are transporting petroleum. The following table shows the differences between a Basic and a Comprehensive OSRP. As shown in Table 1 there is no requirement for rail carriers to contract with oil spill response resource providers; there is no review and approval of the basic OSRP by any regulatory agency; the basic OSRP does not need to be consistent with the NCP or ACP; there is no designated Qualified Individual requirement; and there are no training or exercise requirements for rail carrier personnel who are operating trains carrying Dilbit concerning response to a rail incident.

Table 1. Comparison of basic and comprehensive OSRPs.

Category	Requirement	Type of OSRP	
		Basic	Comprehensive
Preparation	Sets forth the manner of response to a discharge.	Yes	Yes
Preparation	Accounts for the maximum potential discharge of the packaging.	Yes	Yes
Personnel / Equipment	Identifies private personnel and equipment available for response.	Yes	Yes
Personnel / Coordination	Identifies appropriate persons and agencies (including telephone numbers) to be contacted, including the NRC.	Yes	Yes
Documentation	Is kept on file at the principal place of business and at the dispatcher's office.	Yes	Yes
Coordination	Reflects the requirements of the National Contingency Plan (40 CFR Part 300) and Area Contingency Plans.	No	Yes
Personnel / Coordination	Identifies the qualified individual with full authority to implement removal actions, and requires immediate communications between the individual and the appropriate Federal official and the persons providing spill response personnel and equipment.	No	Yes
Personnel / Equipment / Coordination	Identifies and ensures by contract or other means the availability of, private personnel, and the equipment necessary to remove, to the maximum extent practicable, a worst-case discharge (including that resulting from fire or explosion) and to mitigate or prevent a substantial threat of such a discharge.	No	Yes
Training	Describes the training, equipment, testing, periodic unannounced drills, and response actions of personnel, to be carried out under the plan to ensure safety and to mitigate or prevent discharge or the substantial threat of such a discharge.	No	Yes
Documentation	Is submitted (and resubmitted in the event of a significant change), to the Administrator of FRA.	No	Yes

2.3.1.2 *Role of National Transportation Safety Board (NTSB)*

Rail incidents are investigated by the National Transportation Safety Board (NTSB), an independent federal agency. The NTSB makes recommendations toward preventing future incidents based on its findings. Unlike the FRA, the NTSB is not required to weigh the costs against the benefits when considering additional safety measures and it has no regulatory authority. Many of the NTSB's recommendations concerning oil transport by rail are identical to those it previously issued for transporting ethanol by rail. While the FRA has largely agreed with NTSB's recommendations, its rulemaking process involves consultation with industry advisory committees so the FRA must determine which of the many rail safety measures under evaluation deserve priority. Implementing a change in FRA regulations can take years.

2.3.2 Pipelines

The Hazardous Liquid Pipeline Safety Act (HLPSA) of 1979, as amended, provides the statutory authority for the U.S. DOT to establish regulatory standards for the transportation of hazardous liquid by pipelines, including those transporting crude oil.

Within DOT, authority to carry out the act is delegated to the PHMSA, which implements its authority through the Office of Pipeline Safety (OPS). OPS promulgates rules governing the design, construction, testing, inspection, maintenance, and operations of hazardous liquid pipelines. The regulations are intended to establish minimum safety standards applicable to all hazardous liquid pipeline facilities, thereby setting a safety level that all operators must meet across the spectrum of pipeline systems. The regulations cover pipelines that transport crude as well as refined products. There are no requirements for response resources needed for a worst case discharge, as both USCG and EPA requires.

2.3.3 Tank Vessels, Bulk Storage Terminals and Refineries

All tank vessels, bulk storage terminals, refineries, and pipelines are covered by the Clean Water Act, as amended by the Oil Pollution Act of 1990 legislation and the regulations promulgated there from. The regulating authorities, as appropriate are the U.S. Coast Guard for vessels and marine transportation related facilities, the U.S. EPA for non-marine transportation related facilities for compliance with OPA '90 regulations. For response, the Coast Guard and US EPA have a memorandum of understanding that defines the maritime and navigable water areas the CG is responsible for; and the inland areas where EPA takes the lead as on-scene coordinator.

2.3.4 Gaps in Information

The 2013 NOAA study, as well as the research performed throughout this project, indicates that there are only a limited number of policies and regulations that currently exist that explicitly address the transportation of OSPs in the United States (NOAA, 2013). A review of selected USCG Sector Lake Michigan Geographic Response Plans and EPA Region 5 Area Contingency Plans, which includes the Great Lakes region, reveals a similar gap in addressing OSPs spills from any transport mode—rail, pipeline, and vessel—particularly spills of any oils that may submerge/sink.

Below are a number of areas where there appears to be a lack of information and/or regulatory framework to be potential concerns, and are thus considered gaps that USCG and partner agencies should consider in determining ways and means to close those gaps. Recommendations concerning these gaps are covered in Section 5, Conclusions and Recommendations, of this report.

- Pipeline Oil Spill Response Plans (OSRPs) are not consistently integrated with the regional and area contingency planning process.
- Response plans do not address the potential for OSPs to act as non-floating oils in the case of spill. OSRPs treat OSPs as a Group 2 or 3 floating oil. The Responsible Party is required only to prepare for floating oil response and contract with Oil Spill Response Organization (OSROs) that may not have Group 5 oil capabilities. This is also true for other crude oils.
- Area Contingency Plans (ACP) for Areas where Dilbit is transported or stored in their area of responsibility usually do not have oil spill scenarios involving submerged oils. Geographic Response Plans (GRP) of the ACPs, do not usually include submerged oil response information.
- Regulations do not require risk assessments related to oil sands bulk storage or marine transportation related terminals until construction is taking place.
- Current policies do not require pipeline operators, rail carriers, or tank vessels to provide information on the specific type of oil product being transported in a pipeline, train or vessel; therefore, local jurisdictions and local first responders are not kept sufficiently informed by Responsible Parties as to what is being transported or stored in their jurisdictions.
- Oil spill regulations require response organizations to demonstrate equipment deployment capabilities, but do not address testing or validation of *equipment effectiveness* for specific oils. Not all skimmers work equally as well on all types of oil.
- MSDSs currently do not describe the specific type of oil being transported. The lack of adequate material information in the early stages of an incident poses challenges to public and responder health and safety, as well as effective response methodologies.
- Regional and national capacity to respond to an OSP spill is unclear, as most equipment lists do not provide information about applicability to different oil types.
- The USCG and EPA response equipment requirements for Group V oils that may submerge are extremely generic and lack any specificity as to equipment capability, capacity, and effectiveness.
- The physical properties and behavior of the diluent component of oil sands mixtures and the associated potential public health concerns have not been adequately addressed. Lack of diluent information, as to type and volume percentage, for a specific OSP can cause potential public and responder health risks and impact cleanup activities.
- There are uncertainties regarding how weathering affects the environmental fate and behavior of spilled OSPs, particularly under differing conditions of salinity and temperature. That is, what are the conditions, if any, under which spilled OSPs would be over-washed by water, suspended in the water column, or submerged and laying on the bottom of the waterway.
- Information regarding how OSPs will biodegrade in the environment is lacking.
- The risks associated with increased waterborne and rail transport of OSPs are not well-defined.

2.4 Response Planning

Among the regulations and planning activities, it is also essential that the Responsible Party immediately advise the first responders and response contractors, as well as notify the regulatory authorities, that the materials released are oil sands products. This information will make all parties aware of the potential of submergence of the released materials and that they may need to prepare for the potential eventual submergence of the material and select recovery tactics and associated equipment.

OSPs are classified as a Group 3 oil based upon its characteristics prior to a spill into the environment and not on characteristics that might change once the oil is released into the environment, thus the

owner/operator has under contract those response resources that meet 33 CFR Part 155.1050, response plan development and evaluation criteria for vessels carrying Groups I through IV petroleum oil as a primary cargo, which are resources that address floating oils, e.g., booms, skimmers, etc.

For Group 5 oils, the plan holder must identify in the response plan and ensure, through contract or other approved means, the availability of required equipment. Typical surface response equipment used in oil spill response includes sonar, sampling equipment, or other methods for locating the oil on the bottom or suspended in the water column; containment boom, sorbent boom, silt curtains, or other methods to contain oil that may remain floating on the surface or to reduce spreading on the bottom; dredges, pumps, or other equipment necessary to recover oil from the bottom and shoreline; and other appropriate equipment necessary to respond to a discharge involving the type of oil carried. (Authors Note: Realistically, they also need to perform analysis on water samples downstream or separated by varying distances to determine the concentration of toxics dissolved into the water column.)

It should be noted here that the March 2015 Draft *NPREP Guidelines*, Section L, Special Considerations, Number 7, Group V Oils **<u>or Oils that may Exhibit Similar Qualities When Discharged into the Environment</u>** states that, *"Due to the rapid expansion of Group V oils within the U.S. energy market, transportation of Group V oils **<u>or oils that may exhibit similar qualities has increased</u>**. Therefore, plan holders carrying Group V oils **<u>or oils that may exhibit similar qualities</u>** are highly encouraged to carry out emergency procedure exercises, equipment deployment exercises, and IMT exercises focused on scenarios involving Group V oil **<u>or oils that may exhibit similar qualities</u>**."* It is anticipated that the "***or oils that may exhibit similar qualities,***" will, in fact, be OSPs, e.g., Dilbit, etc. (USCG, 2015).

2.4.1 Data Necessary to Plan for Response Strategies

State and local agencies charged with preparation and response to spills and incidents that threaten spills do not possess the data about the product type, volume rail, and pipeline, which is necessary to properly plan for response strategies. Further, no federal or state requirement in existence requires the railroads or pipelines to submit oil product type and volume data at the point of transfer to state and local agencies. As determined in the Enbridge, Michigan and Enbridge Illinois Pipeline spills that occurred in 2010, as well as the 2013, Mayflower, Arkansas, Exxon-Mobil Pegasus incident, there was confusion and misinformation as to the type of material released into the environment. Disclosure of this information is not required and; thus, in the Enbridge, Michigan incident, it took more than a week for federal and local officials to discover they were dealing with a Dilbit spill. Spill response pre-planning has been repeatedly shown to be instrumental in assuring rapid and effective mitigation of spill incidents regardless of the source of spillage or location.

Booth and Macon advise on activities that are focused on gathering relevant response information in advance of an oil sands spill in order to facilitate a timely and effective response (Booth & Macon, 2014a) (Booth & Macon, 2014b). Many of these recommendations can be addressed in GRPs with Area Committees playing a role in the majority of the suggested activities. Booth and Macon make recommendations of a series of logical first steps that local response communities can take to increase their preparedness, training, and outreach in preparation for spills of Canadian OSPs. Some of these preparations are as follows: (see Appendix C for additional recommendations by Booth and Macon)

- Identify locations in the local area of responsibility where oil sands may be encountered. Evaluate the local area and identify the routes of oil sands transport (shipping, rail, and pipeline) as well as the locations of OSP production and storage.
- Update Contingency Plans to account for OSPs. If an OSP is present in the local area, Area and Regional Contingency Plans should be updated to account for these products (Center for Spills in the Environment, 2012). In 2014, the Northwest Area Committee (NWAC) added a section to the Northwest Area Contingency Plan (NWACP) that addresses the presence, response considerations, and best practices for sinking oils (including OSPs) within their area of responsibility (Northwest Area Committee, 2014). The recommendation to update Contingency Plans so that they adequately address OSPs was also voiced by the Alliance for the Great Lakes (Alliance for the Great Lakes, 2013). When conducting Contingency Plan updates, planners should keep in mind that, although OSPs may behave like highly persistent Group V oils (oils that have a specific gravity greater than 1.0) once weathered in the environment, they are often classified as (and subject to the regulations for) Group IV oils (oils that have a specific gravity greater than 0.95 and less than 1.0) due to their physical characteristics as a blended product (NOAA, 2013). It is critical that planners acknowledge and plan for this reality when updating the Contingency Plans to account for the presence of OSPs. Information about the locations where OSPs may be encountered and the areas of deposition where sunken oil could collect or pool should also be included in these Contingency Plan updates.
- Conduct local area exercises that address oil sands spill scenarios. Once the Contingency Plans have been updated, the information outlined in the plan should be assessed by conducting an exercise based on an OSP spill scenario. Federal and State exercise designers should make every effort to include industry partners and plan holders that produce, store, or transport OSPs in their PREP exercises.

2.4.2 Geographic Response Plans (GRPs)

Each oil spill contingency plan is required to include information on resources at risk from oil spills in order to plan for a response to spills. Geographic Response Plans (GRPs) are geographic-specific response plans for oil spills in water. GRPs include response strategies tailored to a specific beach, shore, or waterway; the plans are meant to minimize impact on sensitive resources threatened by the spill. GRPs are created to reduce the time needed to make decisions during the initial response. A GRP provides the responders with essential information about the site, the equipment needed to carry out an effective response, access details, resources at risk from the spill and other information. The goal of a GRP is to ensure that the response to a spill is fast and effective, and that sensitive resources are protected and damages reduced.

GRPs usually have strategies developed for floating oils and they do not address oils that may submerge or sink, such as Group V oils. Some portions of Dilbit and other heavy oils may submerge beneath the water's surface; thus, usually the GRPs in the areas where Dilbit is being transported may not have site specific response strategies developed for submerging or sinking oils.

One of the issues determined in the Washington State Department of Ecology study is as follows (Washington State Dept. of Ecology, 2015):

> *The GRPs also do not address potential responses for potentially submerged or sinking oils. This is a concern for diluted bitumen spills under some conditions, particularly for spills into waters that have high sediment content and are turbulent. The increased handling of oils that are known (designated by the federal regulations as Group V oils) to sink or weather and sink requires updates in the way oil spill response is conducted in the*

northwest. Traditionally, response and contingency planning has focused on containing and recovering surface floating oil through the use of booms and surface skimmers. There are limitations on the ability to model, track, locate and recover submerged oil. Regulations do not take into consideration submerged oil response planning for oils that may weather and sink that are not classed as Group V oils.

2.5 Techniques and Tactics

The following is a summary of the findings in the Counterspil Research paper (Counterspil Research, 2011).

> *"If the spilled oil remains on the water surface for a period of days, then response technologies exist which could be deployed to contain, skim, transfer, and store highly viscous oil.*
>
> *If the spilled oil eventually assumes neutral buoyancy and becomes suspended between the water surface and the bottom, then it is unlikely that any response technologies can be successfully applied to significantly control the spill.*
>
> *If the spilled oil sinks to the bottom, then the literature points to the following possible response techniques and their inherent limitations:*
>
> - *Methods of detecting sunken oil have advanced from sorbent arrays to the USCG's multi-beam sonar and fluorescence spectrometry systems*
> - *Once sunken oil is located, dredging operations using hydraulic submersibles with "open" impeller chambers operated by divers will likely be the primary method applied in recovering the oil. Submersibles and remotely-operated vehicles (ROVs) can be useful to both detect and collect sunken oil but are not known to be widely or quickly available. The three USCG integrated systems, including submersible and ROV platforms as well as submersible dredger are in the developmental stage. Their successful use will still depend on being able to locate sunken oil and the availability of oil accumulations in amounts that warrant their removal."*

2.5.1 Dilbit Oil Spill Tactics

Initially at the Enbridge and Barnaby oil spills, responders used traditional methods to clean up oil floating on the river's surface. These methods include booms, skimmers, and vacuum equipment. The responders in Michigan were not aware of the spilled material being OSPs, but just heavy crude oil (NOAA Office of Response and Restoration, 2014a).

After responders discovered the Dilbit from the Enbridge spill had sunk to the sediment at the river's bottom, they developed a variety of tactics to collect the oil: spraying the sediments with water, dragging chains through the sediments, agitating sediments by hand with a rake, and driving back and forth with a tracked vehicle to stir up the sediments and release oil trapped in the mud. These tactics resulted in submerged oil working its way back up to the water surface, where it could then be collected using sorbent materials to mop up the oily sheen. While these tactics removed some oil from the environment, they might also have caused collateral damage (NOAA Office of Response and Restoration, 2014a).

For the Burnaby spill, much of the oil ended up on shore where standard cleanup techniques were used.

What was learned from the Enbridge spill can help predict some potential environmental impacts of future Dilbit spills. From the Enbridge spill, we know that Dilbit will weather (undergo physical and chemical changes) rapidly, becoming very dense and possibly sinking in a matter of days. If the Dilbit reaches the sediment bed, it can be very difficult to get it out; bringing in responders and heavy equipment to recover the oil from the sediments can injure the plants and animals living there (NOAA Office of Response and Restoration, 2014a).

2.5.2 Detecting and Monitoring Sunken Oil

The NOAA study states that, based on USCG research, multi-beam and imaging sonars are the most effective technologies for conducting wide area detection surveys and searching for large pools of subsurface oil (NOAA, 2013). The sonars are most effective in detecting subsurface pools if the equipment is deployed before the oil breaks up. However, the resolution of these devices remains relatively low, impairing their effectiveness. Laser systems and narrower beam sonars are better suited to narrow areas and determining the amount of oil present. (Author Note: Laser systems have a short range, e.g., just a few meters at best. As a result, it may be better to use slug flow techniques for random spaced sampling.) The following table includes a summary of other detection and monitoring technologies that have been evaluated. It should be noted that most of these technologies are only good for bulk oil.

Table 2. Detection and monitoring technologies.

Technology	Analysis
Snare Sampler (Counterspil Research, 2011); (Michel J. , 2006)	• Specifically used to detect oil at various depths in the water column • Produces time-series data • Time and labor intensive
Vessel-Submerged Oil Recovery System (V-SORS) (Counterspil Research, 2011); (Michel J. , 2006)	• Can detect both pooled and mobile oil moving along the bottom • Relatively efficient • Time and labor intensive • Susceptible to snagging on bottom
Side-scan sonar data (Counterspil Research, 2011); (Michel J. , 2006)	• Provides good spatial coverage and visualization of large accumulations and bottom features • Effectiveness diminishes as the oil spreads and the water becomes rough • More successful in detecting the trenches and other bottom features that contain pooled oil instead of the oil itself
RoxAnn (Counterspil Research, 2011); (Michel J. , 2006)	• Used to differentiate seafloor bottoms
Remotely-operated underwater video (Counterspil Research, 2011)	• Successfully provides estimates of frequency and size of oil accumulations • Cannot always determine exact oil position • Effective with visibility exceeding 0.5 meters, but it does not generate a wide view
Sorbents attached to weights (Counterspil Research, 2011)	• Ineffective
Sorbent drops and sediment cores (Counterspil Research, 2011)	• Not effective for mobile oil in the water column

Table 2. Detection and monitoring technologies (Continued).

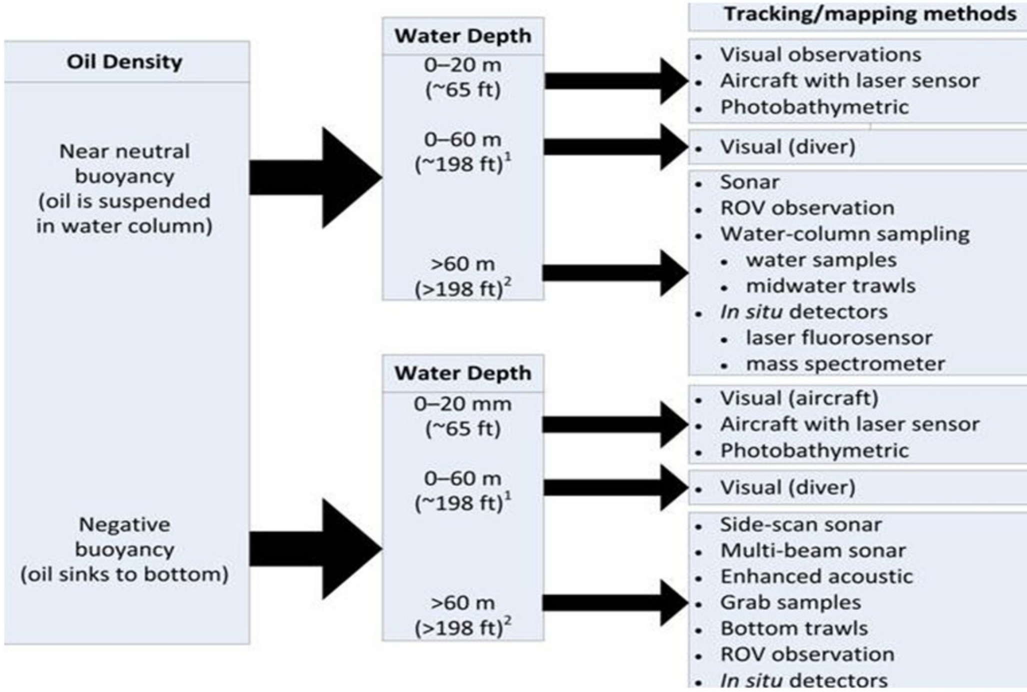
Technology	Analysis
Snare Sentinels (Counterspil Research, 2011); (Michel J. , 2006)	• Too time and labor-intensive for widespread use
Airborne Hyperspectral fluorescent LIDAR	• Successful in detecting oil suspended in the top few meters below the water surface (Authors Note: Will actually only see the top few mm's. However, nearby materials will leach into the water and thence to the surface where they will appear as the emission referred to as fluorescence.)
RESON Sonar System (Hansen et al., 2009)	• Positively identifies 87 percent of sunken oil targets. • Has a false alarm rate of 24 percent
EIC Fluor sensor (Hansen, 2014)	• Can be attached to ROVs or other platforms • GIS input fluctuates and direct mapping is not possible
Side-looking Airborne Radar, UV, & IR	• Unable to penetrate water

Source (NOAA, 2013)

The following is a summary of observations and techniques that have been found to be effective for detecting and monitoring sunken oil:

- Experienced personnel are required to determine accurate observations due to the possible occurrence of false sightings.
- Techniques that range from simple sorbents and visual observations to sophisticated instrumentation have been used during the response to actual spills of submerged oil.
- Video, including cameras on ROVs, may only be effective in areas where visibility exceeds 0.5 m. Sea conditions, current, oil properties, and sedimentation affect visibility.
- RESON Sonar System was identified by the USCG as a promising multi-beam sonar system that has successfully detected sunken oil. It can be attached to multiple platforms, but the image resolution generated is still not adequate for widely dispersed oil spills.
- EIC Fluorosensor is another USCG identified system based on fluorescence spectrometry that can identify spilled heavy oil aromatics. Its small size might allow attachment to ROVs or other platforms. (Authors Note: It is sensitive, but it is only useful up to the distance that the excitation beam can reach. The returning light is similarly attenuated by intervening sediments etc.).
- Airborne hyperspectral fluorescent LIDAR successfully tracked submerged oil during the Deepwater Horizon BP oil spill in the Gulf of Mexico in 2010. Limitations of this technology were not reported.

Figure 7 illustrates the tracking/mapping methods as a function of depth for oil suspended in the water column and for oil that sinks to the bottom (Hansen, 2014).



Source: (Hansen, 2014)

Figure 7. Tracking/mapping methods for sunken oil.

2.5.3 Containment of Sunken Oil

Containment of submerged oil remains mostly in the conceptual stage. To the extent that the technologies shown in the following table, which summarizes the potential containment methods for sunken and submerged oil, have proven effective; these applications have been limited to low-flow zones or depressions.

Table 3. Potential containment methods for sunken and submerged oil.

Technology	Analysis
Trenching and Berming	• Does not work if the oil is suspended
Pneumatic barriers (air bubbles) (Counterspil Research, 2011)	• Limited information on this method • May aerate oil, creating foam, which would change the density and reduce the oil's tendency to sink. • Effective at "*protecting a water intake at currents of less than 0.75 knots*"
Deep-skirted booms (Counterspil Research, 2011)	• Developed to contain Orimulsion • May be effective, but have limited information
Bottom booms, filter fence, trenches, and booms (Counterspil Research, 2011)	• Can be coordinated with recovery and are quick and easy to deploy • Highly dependent on bottom conditions • Seabed booms for sunken oil have not been tested in a real situation
Trawl nets (Counterspil Research, 2011)	• Have proven effective (other than fine mesh nets) • Made specifically for heavy oil recovery
Sorbent barrier/fence (Michel J. , 2006)	• Never tested • Engineering design inadequate to assure it would function properly • If manipulated, it can be easily fabricated to meet site-specific contexts

Source: (NOAA, 2013)

The only successful containment of submerged oil located on the bottom of a water body has occurred naturally in low-flow zones and depressions. Other techniques such as seabed booms, fine meshed nets and trawls, conventional deep-skirted booms and pneumatic barriers have not been proven in real events; or have significant limitations.

2.5.4 Recovery Techniques for Sunken Oil and Their Impacts

If oil is suspended in the water column, little can be done besides detecting the oil (Counterspil Research, 2011). USCG research suggests that a hopper dredge or large duck-bill system has the highest potential for use in recovery efforts based on timing, operational limits, recovery efficiency, remobilization, cost, and safety (Michel J., 2006). Potential recovery methods for sunken and submerged oil are summarized in the following table.

Table 4. Potential recovery methods for sunken and submerged oil.

Technology	Analysis
Hydraulically-driven submersible dredge pump with a diver-directed suction hose (Counterspil Research, 2011)	• Recovered 900 gallons of submerged, pooled oil from small trench during M/T Athos • Diver directed hoses led to a slow recovery, especially since the oil was moving
Centrifugal Pump (Counterspil Research, 2011)	• Resulted in droplet formation • Used with a lower rpm Foilex TDS-150 Archimedes screw pump as well as a 4-stage decanting system to effectively reduce water content
Clamshell dredges (Counterspil Research, 2011)	• Successful when oil solidifies
ROVs and mini-subs (Counterspil Research, 2011)	• Potential to recover oil from greater depths • Marine Pollution Control has been testing a mini submarine mounted with a suction recovery system
Nets (Counterspil Research, 2011)	• Messy and largely ineffective
Dredging (Counterspil Research, 2011)	• Effective • Generally limited to 50 meters water depth • Pneumatic dredgers can operate in greater depths • Fastest method of recovering sunken oil but generates a large volume of sediment and water that needs to be stored • Also need to consider the benefits of removing oil against seabed disturbance

Source: (NOAA, 2013)

The following are further descriptions of the techniques that have been found to be effective for recovering sunken oil, taken from the above list and from Hansen (2014):

- Clamshell dredgers, barge-mounted excavator dredgers, and suction dredgers have been applied successfully in actual spill responses. Dredgers are generally limited to 50m water depth, but pneumatic dredgers can operate in greater water depths.
- Dredging is the fastest method of recovering sunken oil but generates large volumes of waste water and sediment. Most thorough method of removing oil from the bottom, but also the most intrusive and damaging. Oil removal versus seabed disturbance needs to be considered as it may mobilize contaminants in the bottom sediments.

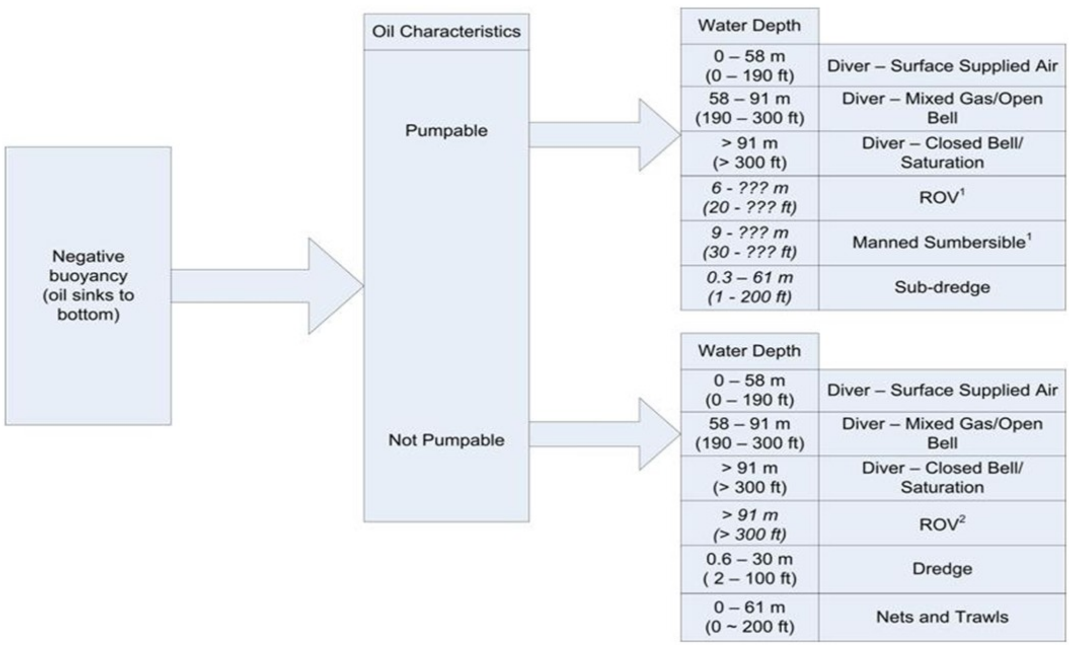
- A hydraulically-driven submersible dredge pump attached to a diver-directed suction hose successfully recovered submerged oil during the M/T Athos spill. A steam-injection duckbill attachment on the suction hose intake reduced friction losses, while a steel debris box decreased the likelihood of objects jamming the pump. Archimedes screw pumps reduced droplet formation.
- During the DBL-152 barge incident, hydraulic submersibles with "open" impeller chambers (e.g., MPC's model KMA axial/centrifugal pump) worked well when divers directed the operations. Significant quantities of water, sediment, and marine organisms can also be removed.
- When pumps are applied to submerged oil, the volume of oil actually recovered can be low relative to the amount of oil released. Support logistics can be complex, repositioning of the work platform difficult, and recovery rate slow as mobile oil spreads.
- Manual removal using divers is slow but damage to the local environment is minimized.
- Bottom Nets and Trawls can cause serious damage as they can disrupt or destroy bottom habitat and capture organisms. There was limited success for these during the Deepwater Horizon Response.
- Remotely-operated vehicle (ROV) technology and mini submarines appear to offer potential to recover oil from greater depths than is possible with divers. Stranded oil has the potential to sink so that more advanced, available techniques should be applied to recover oil from beaches to prevent this.
- Design improvements to dredgers include nozzle and other modifications to reduce water and sediment intake during underwater pumping.
- The USCG program to develop three integrated recovery systems that also incorporate detection and waste stream processing appears to be the most promising of the initiatives to improve submerged oil technologies. The following three technologies are the culmination of applying the collective knowledge and experience garnered from actual spill events, research programs, and workshops:
  - The Sea Horse system incorporates high-resolution sonar, 3-D positioning, ROVs, commercially available generators, pumps with nozzles and hoses, plus a 5-step decanting process.
  - The Marine Pollution Control (MPC) manned submersible and multi-staged separation process features enhanced oil detection sensors (i.e. multi-beam sonar and polarized fluorescence), a direct view and controls. Enhanced pump and debris control are planned for development.
  - The Tornado Motion Technologies Sub-Dredge is a remote-controlled vehicle that uses underwater cameras and a high volume EDDY Pump that targets specific materials in order to reduce turbidity and residuals. The depth of contaminant removal can be adjusted in millimeter increments. A rotating shroud sheds rocks and debris.
- Various skimmers have been commercially developed world-wide that can be applied to highly viscous oils but not to oils that submerge beyond approximately 0 – 30 cm below the water surface. The oil must also be at a temperature below its pour point for the skimmers to function properly.
- Capping may be used where removal is impractical or would only spread the contamination.
- No Action should be considered when the impact of the oil appears minimal in relation to the habitat disruption and marine organism mortality associated with removal. (Authors Note: One problem is that realistically we don't know the long term fate of all parts of the oil. Is it all biodegraded or does it gradually dissolve into the water table; or does it get covered over with additional sediment only to release over the course of decades?)

Other related issues include:

- Pump technologies that are primarily based on the Archimedes' screw principle have been developed that now include annular water injection; and is a key component of the commercial skimming equipment developed in Denmark, Sweden, Norway and Finland.

- The pumps applied to submerged oil are used directly in the recovery process rather than more traditional transfer operations during surface skimming.
- Transfer technology should not be a limiting factor when dealing with viscous, submerged oils.
- Multiple-stage decanting and storage equipment used to process the liquid and sediment stream recovered by dredgers is a key component of the USCG program to develop and test three integrated submerged oil spill control systems. This holds the most promise of resolving the waste stream issues identified at actual spill events and submerged oil workshops.

At the September 2014 Group V Oil Forum, Hansen explained sunken oil recovery techniques. The following Figure 8 lists these techniques. Hansen, in his presentation, further explained recovery technique impacts as shown in Figure 9 (Hansen, 2014).



Source: (Hansen, 2014)

Figure 8. Recovery techniques for sunken oil.

Source: (Hansen, 2014)

Figure 9. Recommended recovery techniques for sunken oil.

2.5.5 Timeliness

Prompt response to an OSP spill into the waterway is absolutely essential. To summarize, the initial stages of an OSP spill will generally require the following actions:

- The response will be similar to a crude oil spill with response resources focused on surface response methodologies, e.g., booms, skimmers, etc., and public and responder safety, e.g., air monitoring, respiratory protection, public notifications, etc.
- Identify methods and equipment that might be effective for recovering oil on the surface or bound to the sediment that may submerge below the surface. The more OSP that is removed from the surface quickly, the less product will be susceptible to submerge as the diluents evaporate and the bitumen mixes with sediment.
- Establish an air monitoring and safety program to protect the public; and establish the safety protocol for the responders and obtain the needed air monitoring and respiratory protection equipment.
- Identify environmental, economic, and cultural resources at risk and assess the extent of the spill both surface and subsurface, including drinking water intake risks.
- Identify the characteristics of the OSP spilled, beyond the MSDS, to assist in establishing safety protocols and determining cleanup strategies.
- Knowledge of the specific diluent and the characteristics of the OSP would be central to any response actions to be taken.
- Important to provide accurate information to the public about an OSP spill, including information on any known toxicity issues and the closure of any fisheries, which includes challenges as to the determination of length of time toxic characteristics disappear out of the fats in fish.
- Continued outreach to the public must occur throughout the cleanup process to keep the public informed about the progress of the response and any restoration efforts.

In order to quickly respond to an OSP spill, the following are important preparations:

- Jurisdictional authorities having awareness that OSPs are being transported, handled, or stored in or through a geographic area.
- The necessary response (tracking, monitoring, containment, and removal) equipment and trained personnel available to rapidly respond.
- Have up-to-date Area Contingency Plans and Geographic Response Plans that have evaluated and planned for a spill of a product that a portion of which may submerge below the surface.
- Responders in the geographic area have exercised to an OSP spill scenario as part of NPREP.
- Several states have convened work groups or panels that reviewed the situations in their state. Descriptions of the findings and recommendations that may affect CG prevention and response missions are described in Appendix E.

3 RISK ASSESSMENT

Spills generally occur from infrastructure conditions (either normal and long-term use or natural weather occurrences) or human error, and sometimes a combination of both. The spill could result in environmental damage or danger to responders and the general public in both the water and the air. The threat of fire or explosion is always present when hydrocarbon products spill near a heat source. Finally, the impact to the surrounding environment may have serious consequences for the area affected and beyond. Details about transportation infrastructure are continued in Appendix B. The risk areas addressed by this section are:

- **Infrastructure Conditions**: The age and quality of the pipeline, rail and vessel infrastructure is a key aspect to predict risks. Weakened structures may be more susceptible to damage when exposed to severe weather conditions.
- **Human Error**: This area is harder to predict. The assumptions used for worst case discharges and likely discharges greatly influence the final volume amounts that are used for planning.
- **Health Risks**: These risks apply to both the air that may be inhaled and the water that may be ingested.
  - **Air Contamination:** The diluents used in Dilbit to reduce the viscosity of the oil to allow its transport by pipeline contain benzene and other potential carcinogens in a higher amount than other crude oils. When a Dilbit spill occurs in a marine environment, the lighter components of the crude evaporate into the air and the heavy oil separates. After the Kalamazoo spill, health department surveys found that more than 300 residents living near the spill suffered ill effects in the following weeks and months, including severe headaches, nausea, and respiratory problems (Lydersen, 2011).
  - **Water Pollution:** The Great Lakes, their connecting channels and the St. Lawrence River represent the largest system of freshwater resources in the world. More than 36 million people (approximately 8 percent of the U.S. population and 32 percent of the Canadian population) depend on the Great Lakes for their drinking water supply. In the United States, 2.5 million miles of pipeline come close or cross through fresh water aquifers, which millions of people depend on for fresh water. A pipeline rupture that spills Dilbit or crude oil is a serious risk to the fresh water in the United States, which could have disastrous consequences.
- **Fire and Explosion:** To get to refineries on the East and West coasts and the Gulf of Mexico, oil shipments travel through more than 400 counties, including major metropolitan areas according to routing information obtained by the Associated Press. The DOT predicts that trains hauling crude oil or ethanol will derail an average of ten times per year over the next two decades, causing more than $4 billion in damage and possibly killing hundreds of people if an accident happens in a densely populated part of the United States (Associated Press, 2015). Recent train derailments involved massive explosions and fire due to the volatility of the Dilbit or crude oil being transported.
- **Environmental Risks:** Impact to the plants, animals and other living organisms of an area is a major concern if oil is released and not mitigated quickly. With few case studies at this time, assessments during an accident may be difficult.

3.1 Infrastructure Conditions

The age and quality of infrastructure may be a factor in increased risks for spills, especially for pipelines, trains and rail lines, and transshipment sites. According to the Office of Pipeline Safety, much of the pipeline infrastructure has been in place for decades. In the Great Lakes States, 55 percent of the pipelines

were built prior to 1970. Canada's National Energy Board statistics from July 2011 show that approximately 48 percent of Canadian pipelines carrying hazardous liquids were installed more than 30 years ago. In the United States, more than half of the pipelines are at least 50 years old (Groeger, 2012).

Studies of FRA data show that derailments cause 60 percent of freight-train accidents. The major causes of derailments are broken rails or welds, buckled track, obstructions, and main-line brake malfunctions. Some derailment incidents, such as the one in Aliceville, Alabama, point to failure of trestles; which are sometimes antiquated and not always adequately maintained. The most common risk associated with shore-side transshipment facilities relate to technical failure and defects of equipment, such as an oil loader that can cause oil to spill.

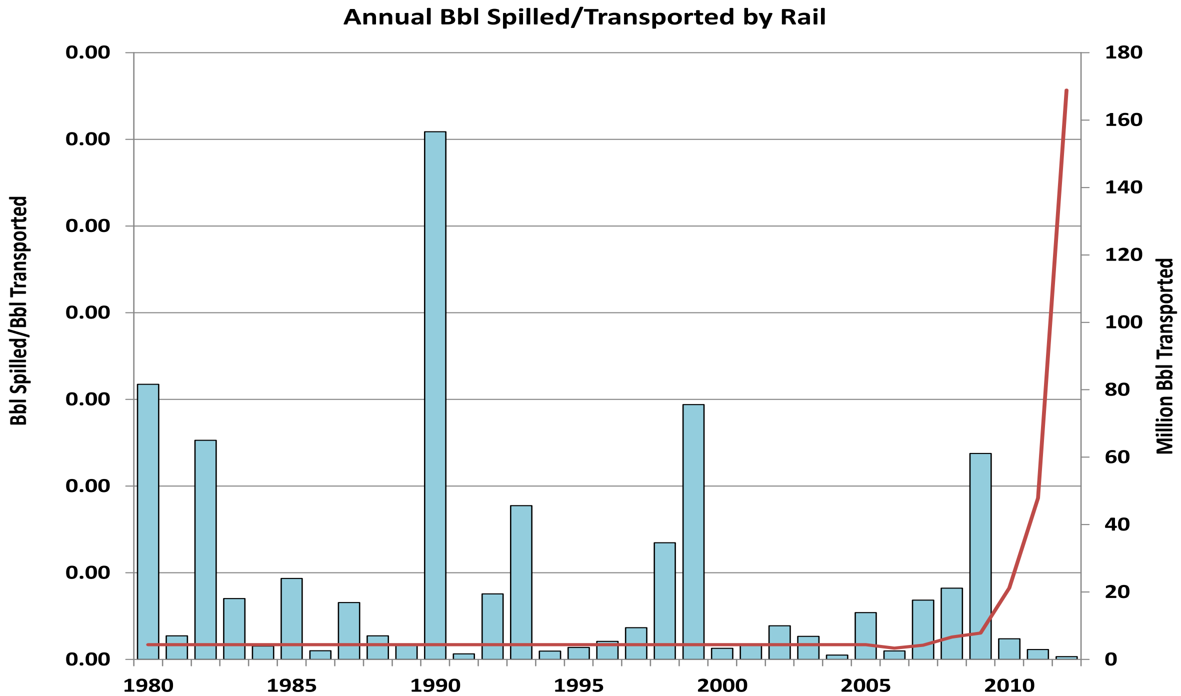
3.1.1 Rail Infrastructure

The U.S. rail network is made up of more than 160,000 miles of track, 76,000 rail bridges, and 800 tunnels across the nation. They are shared by all operators moving freight and passengers. The 565 U.S. freight railroads are categorized into three classes based on their distance served and earnings—seven Class I freight railroad systems; 21 regional or Class II railroads; and 537 short line or Class III railroads. The American Society of Civil Engineers 2013 report advised that, in 2010 alone, freight railroads renewed the rails on more than 3,100 miles of railroad track, equivalent to the distance from the east coast to the west coast (American Society of Civil Engineers, 2013).

During the last decade (2003–2012), throughout the United States, an average of 96,600 gallons of oil spilled annually from trains, or approximately 0.000086 gallon spilled for every gallon transported. This rate means that, on average, one gallon of oil is spilled for every 11,628 gallons transported by rail. The rate of spills per barrel of transport has varied from year to year, but reached an all-time low in 2012 with a spill rate of one gallon spilled per 62,500 gallons transported. In 2012, nearly 7.1 billion gallons of oil were transported by rail and 110,250 gallons spilled (Washington State Dept. of Ecology, 2015).

Another researcher has estimated the spill incident rate specifically for crude-by-rail unit trains as 0.81—2.08 incidents per billion ton-miles, which contrasts with the rate of 0.56 to 0.58 incidents per billion ton-miles of pipeline transport. The magnitude of spills for the crude-by-rail spills is 690 to 2,800 gallons per incident. For pipelines, the spill volume is 11,100 to 11,300 gallons. This is based on a limited data set.

Figure 10 shows annual oil spillage by rail between 1980 and 2010, the red line refers to the right axis. Table 5 lists rail derailments with crude spillage between 2013 and 2015.



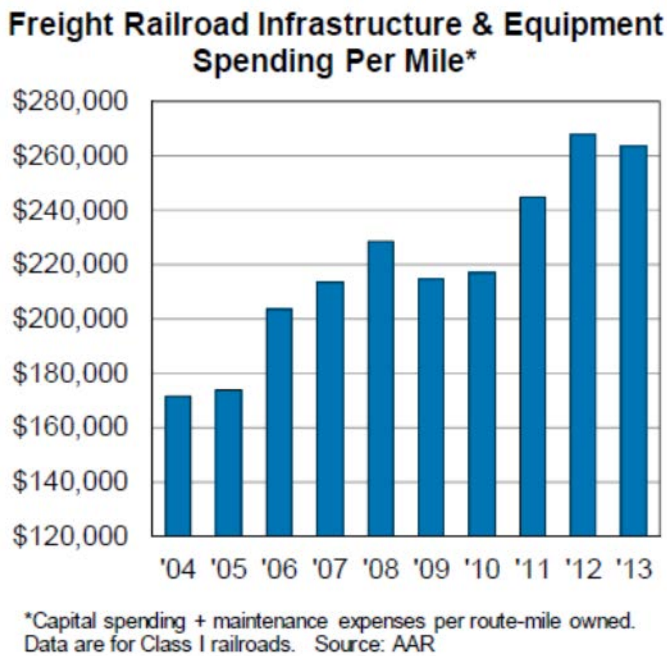
Source: (Etkin, 2015)

Figure 10. Annual oil spillage per barrel of oil transported by rail (1980–2010).

Table 5. Crude by rail derailments with spillage - tank car numbers (2013–2015).

Location	Derailed Cars	Cars with Spillage	Total Cars	% Derailed	% Spilled from Total Train	% Derailed Cars with Release
LaSalle, Colorado	6	1	100	6%	1%	17%
Vandergraft, Pennsylvania	19	1	120	16%	1%	5%
Plaster Rock, New Brunswick	17	5	n/a	n/a	n/a	29%
Lac-Mégantic, Quebec	63	5	72	88%	7%	8%
Aliceville, Alabama	30	12	90	33%	13%	40%
Casselton, North Dakota	20	20	106	19%	19%	100%
Lynchburg, Virginia	17	3	105	16%	3%	18%
Gainford, Alberta	4	0	n/a	n/a	n/a	0%
Parkers Prairie, Minnesota	14	3	94	15%	8%	21%
Boomer Bottom, West Virginia	26	14	109	24%	13%	54%

The Association of American Railroads states that America's freight railroads spent $575 billion on infrastructure from 1980 through 2014, including more than $25 billion annually since 2012 (Association of American Railroads, 2015). The following figure provides two charts showing investments in the railroad infrastructure.



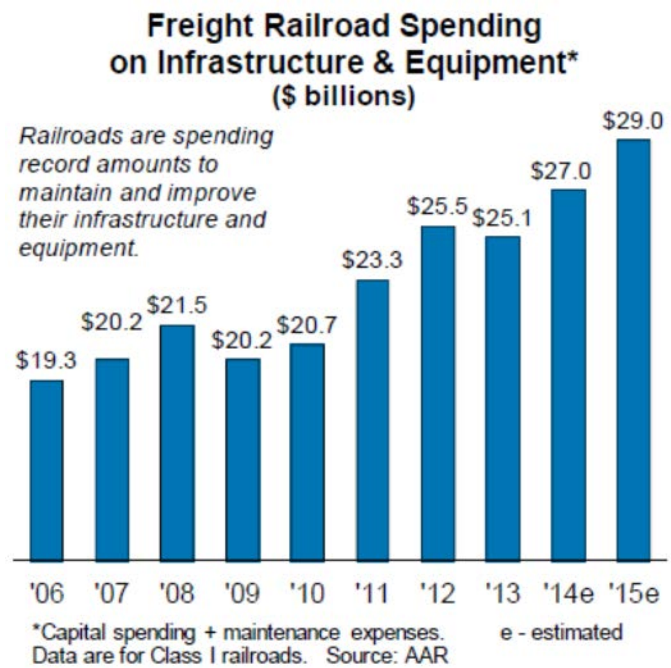


Figure 11. Freight railroad infrastructure investment.

3.1.2 Pipeline Infrastructure

Pipeline is the favored mode of oil transportation in North America. Approximately 70 percent of OSPs produced in Alberta is shipped to Midwest refineries via pipeline. As of 2009, of the 26 refining facilities that can process the heavy, sour oil sands crude, 12 are located in states bordering the Great Lakes. Increasing production in Alberta will continue to drive industry movement toward pipeline construction to support transit of oil sands crude into the U.S. Midwest for refining (Great Lakes Commission, 2015b).

The age and quality of the pipeline infrastructure are important contributors to oil spill risk in the Great Lakes-St. Lawrence River region. Incident data collected by PHMSA show that the most common cause of spill incidents is pipeline infrastructure failure and is shown in Figure 12.

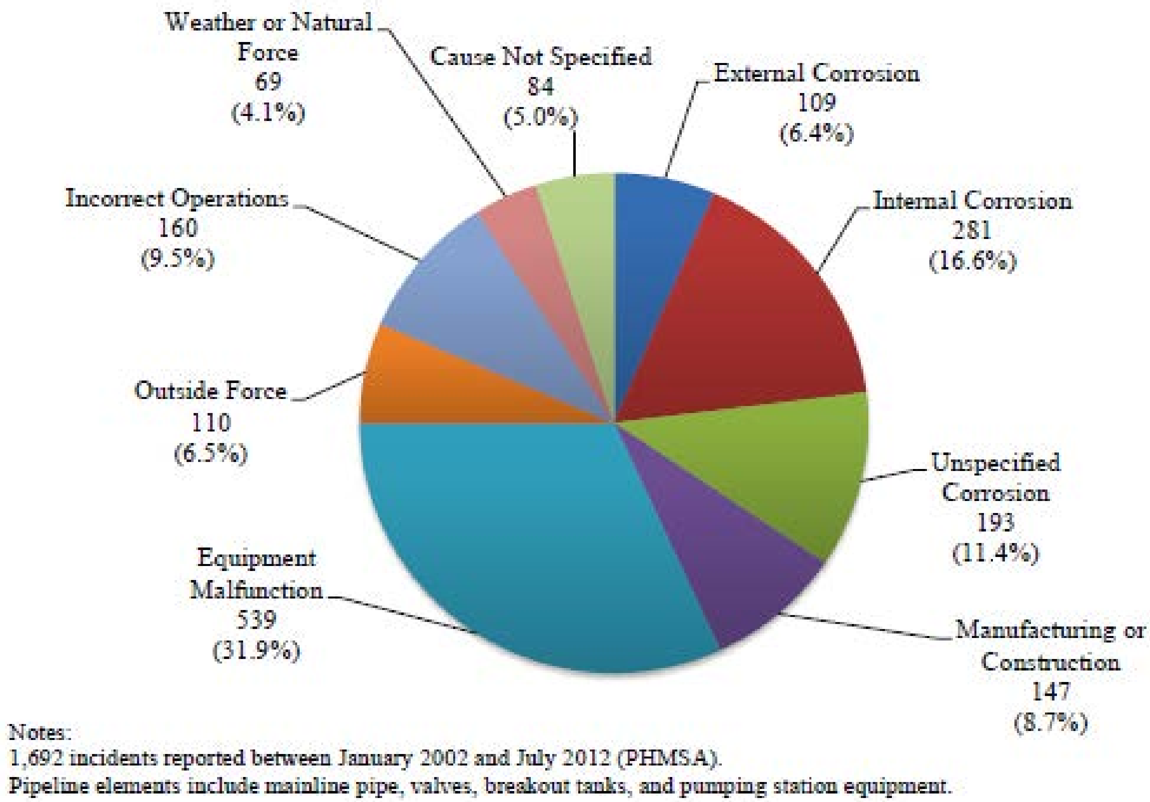


Figure 12. Causes of oil spill incidents.

The Great Lakes Commission states (Great Lakes Commission, 2015c):

> *"Over time the quality of pipeline performance declines due to material deterioration, cracks from corrosion, erosion and defective welding. Examples of pipelines potentially at risk from these factors are the two Enbridge pipelines that lie below water to the west of the Mackinac Bridge in northern Michigan. These pipelines were installed in 1953, more than 60 years ago, and have never been replaced. Corrosion and material and weld failure accounts for 60 percent of pipeline failure and rupture incidents resulting in an oil spill."*

In a Scientific American article, David Biello attempts to answer the question: Have recent pipeline spills been caused by a combination of aging infrastructure and new types of oil? There are conflicting opinions regarding the effect of transporting Dilbit via pipeline. Critics claim that pipelines carrying Dilbit operate at higher temperatures, which have been linked to corrosion; they operate at higher pressures, which could lead to increased risk of leaks and ruptures. Other studies, such as a study from the Alberta government, cast doubt on the notion that Dilbit is worse for pipelines than other oils. Studies found that Dilbit is not corrosive at pipeline temperatures as high as 65 degrees Celsius (Biello, 2013).

A fact sheet developed by the American Petroleum Institute (API) and the Association of Oil Pipelines (AOPL) advises that: (API & AOPL, 2013)

> *"PHMSA regulations require that pipeline operators have a corrosion management program in place for their pipelines. This includes consideration of the use of corrosion*

inhibitors and cleaning pigs to reduce the likelihood of internal corrosion in pipelines. These measures are especially important in pipelines where there is not turbulent flow, which keeps water and sediment which are common in crude oils from settling and promoting corrosion. Diluted bitumen has been transported safely in the U.S. for more than 40 years. PHMSA accident reports since 2002 show zero internal corrosion-related releases from pipelines carrying diluted bitumen. Also, there are no known examples before 2002 of corrosion-caused failures on U.S. pipelines carrying diluted bitumen."

More operating crude oil pipeline (nearly 14,000 miles) was built in the 1950s than in any other decade. The next closest decades (1960s, 2000s, and 1940s) each only have around 7,000 miles. The graph in the following figure shows the age profile of existing U.S. crude oil pipeline. The data in the figure only tells the age of pipelines that are currently in use, it does not show how many total miles of crude oil pipeline were built in each decade but are no longer operating.

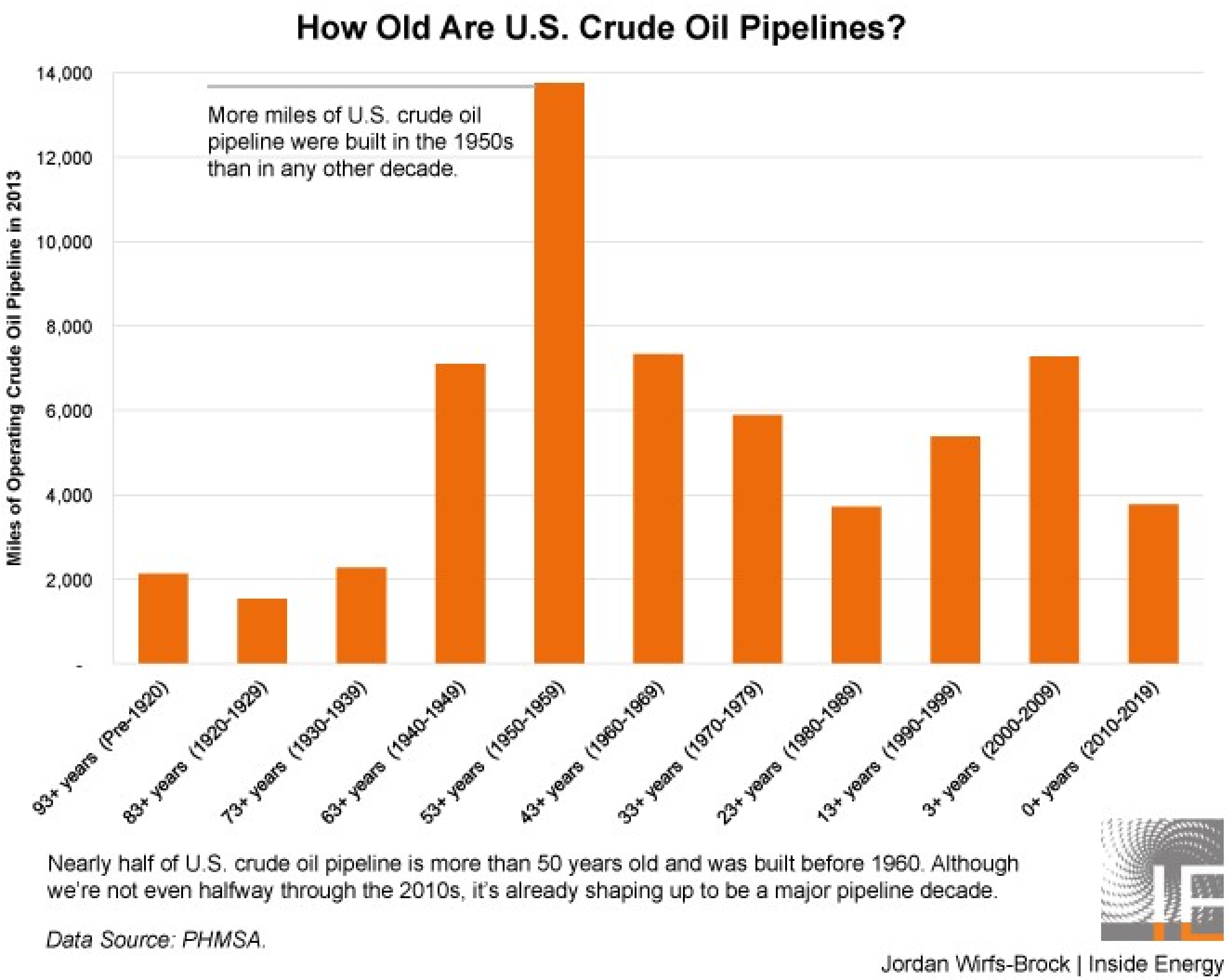
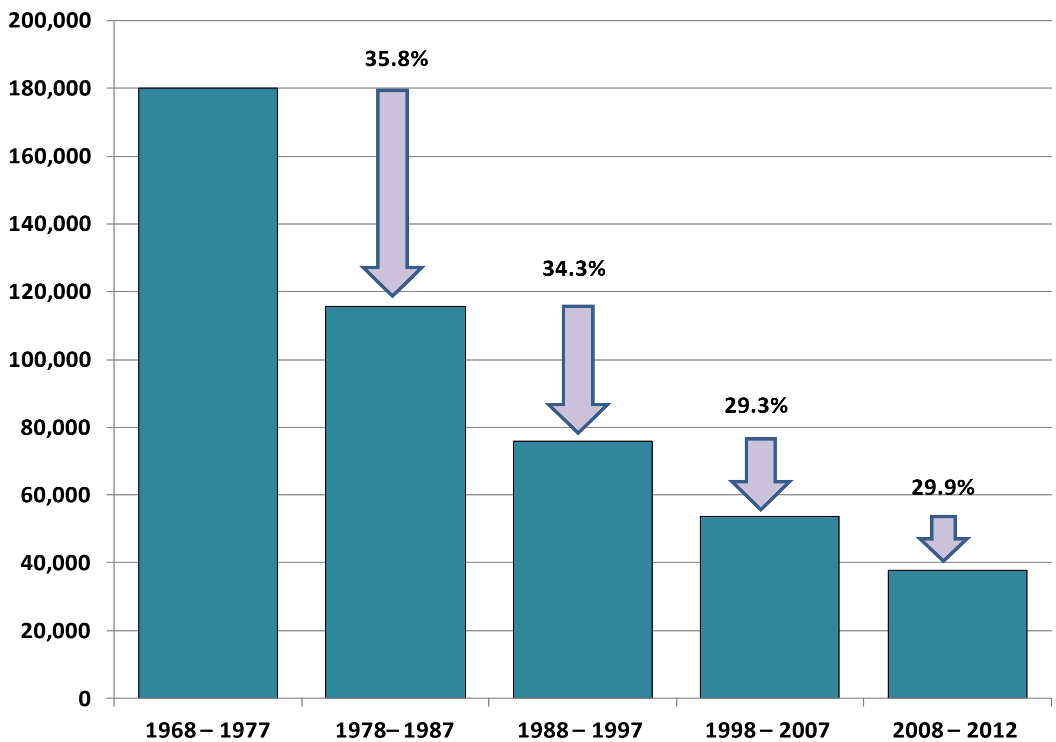


Figure 13. Age of U.S. crude oil pipelines.

Dagmar Schmidt Etkin has analyzed historical data and case studies and concluded the following: (Etkin, 2014)

> *"Crude pipeline spills in inland (non-offshore) areas of the US that occurred during the years 1968 through 2012 were analyzed with respect to frequency and volume. A total of 5,755 incidents of at least one gallon were included. Data on spills of less than one barrel (42 gallons) were not available for the time period prior to 2002. Overall, there was a steady reduction in the annual numbers of spill incidents that occurred from crude pipelines. During the last five years, there has been an average of 157 spills per year."*
>
> *"The volume of spillage has decreased significantly over the 45-year time period so that on average, during the last five years the spillage volume represented only 17% of the volume that was spilled during 1968 through 1972. The distribution of spill volumes is such that the median spill (half smaller, half larger) is 95 bbl. The 90th percentile volume is 950 bbl. Only 5% of spills are larger than 2,500 bbl., 1% is larger than 9,500 bbl. During the last decade, there has been a shift towards smaller spill volumes."*

The average annual volume of spillage from crude pipelines has steadily decreased over the last decades. That is, when a spill occurred during a particular time period, it was, on average, smaller than a spill in a previous time period (see Figure 14).



Source: (Etkin, 2014)

Figure 14. Average annual crude pipeline spillage volume decreases (1968–2012).

Crude pipeline spills are distributed geographically in the contiguous United States, as shown in Figure 15, for all years. The locations of the spills are based on the locations of crude pipelines and the degree of activity in each pipeline. There are higher concentrations of crude pipeline spill numbers in particular

regions due to more pipeline transmission through these areas. However, the highest spill volumes are sometimes based on a smaller number of larger-volume incidents.

Source: (Etkin, 2014)

Figure 15. Crude pipeline spills in the contiguous states of the U.S. 1968–2012**.**

Risks to the public from hazardous liquid pipelines result from the potential for an unintentional release. Releases of a product carried by these pipelines can impact surrounding populations, property, and the environment, and may result in injuries or fatalities as well as property and environmental damage.

These consequences may result from fires or explosions caused by ignition of the released product as well as environmental damage, impact to wildlife, or contamination of drinking water supplies from water intakes from surface water sources and ground water.

The pipeline safety statistics from 2000–2009 reported 411 spill incidents from Canadian pipelines and 3,318 spill incidents from the U.S. pipelines. Within the eight Great Lakes states, 559 hazardous liquid spill incidents occurred in the years 2004–2010, resulting in property damages of over $1.1 billion. Although data from Canada's NEB and the U.S. DOT show that pipelines result in fewer oil spill incidents and personal injuries than road and rail, this high-volume transmission mode experienced large spills in the recent past, which demonstrated that the cumulative impact of a spill on the environment, economy, and human health of the affected region can be serious.

Determination of the risk of a pipeline release requires an assessment of both the likelihood and the consequences of a release. To inform its review of the likelihood, the U.S. Department of Transportation asked the National Research Council (NRC) to convene an expert committee to study whether shipments of Dilbit differ sufficiently from shipments of other crude oils in such a way as to increase the likelihood of releases from transmission pipelines.

The NRC committee analyzed information in a variety of forms. Early in its deliberations, the committee provided a public forum for individuals to contribute information relevant to the study. The committee reviewed pipeline incident statistics and investigations; examined data on the chemical and physical properties of shipments of Dilbit and other crude oils; reviewed the technical literature; consulted experts in pipeline corrosion, cracking, and other causes of releases; and queried pipeline operators about their experience in transporting Dilbit.

The review of incident data revealed the ways in which transmission pipelines fail. Some failures can be affected by the properties of the transported crude oil, such as its water and sediment content, viscosity and density, and chemical composition. These properties were examined for Dilbit and a range of other crude oils to determine whether pipelines transporting Dilbit are more likely to experience releases. In addition, the committee considered whether pipeline operations and maintenance (O&M) practices, including internal and external corrosion control capabilities, are subject to changes that inadvertently increase the likelihood of release when pipelines transport Dilbit.

The following are the findings and recommendations of the NRC Committee (Transportation Research Board, 2013):

- ***Central Findings***

  The committee does not find any causes of pipeline failure unique to the transportation of diluted bitumen. Furthermore, the committee does not find evidence of chemical or physical properties of diluted bitumen that are outside the range of other crude oils or any other aspect of its transportation by transmission pipeline that would make diluted bitumen more likely than other crude oils to cause releases.

- ***Specific Findings***

  - *Diluted bitumen does not have unique or extreme properties that make it more likely than other crude oils to cause internal damage to transmission pipelines from corrosion or erosion.*
  - *Diluted bitumen does not have properties that make it more likely than other crude oils to cause damage to transmission pipelines from external corrosion and cracking or from mechanical forces.*
  - *Pipeline O&M practices are the same for shipments of diluted bitumen as for shipments of other crude oils.*

3.1.3 Pipeline versus Railroad Statistics

Figure 44 shows rail and pipeline incidents between 2009 and 2013 per billion barrels transported. This figure shows that from 2009 to 2013 the frequency of accidents is approximately 22 accidents per billion barrels of oil transported by pipeline. During this same period, the frequency of accidents per year for rail-transported oil is significantly higher, varying between 120 and 720 accidents per billion barrels of oil transported by rail. Figure 16 also illustrates the quantity of oil spilled in thousands of barrels spilled per billion barrels transported. The quantity of oil spilled is generally higher for pipeline-transported oil compared to rail transported oil with the notable exception of 2013. Two major train derailments in 2013 resulted in a significant spike in the quantity of oil spilled in rail-transported incidents.

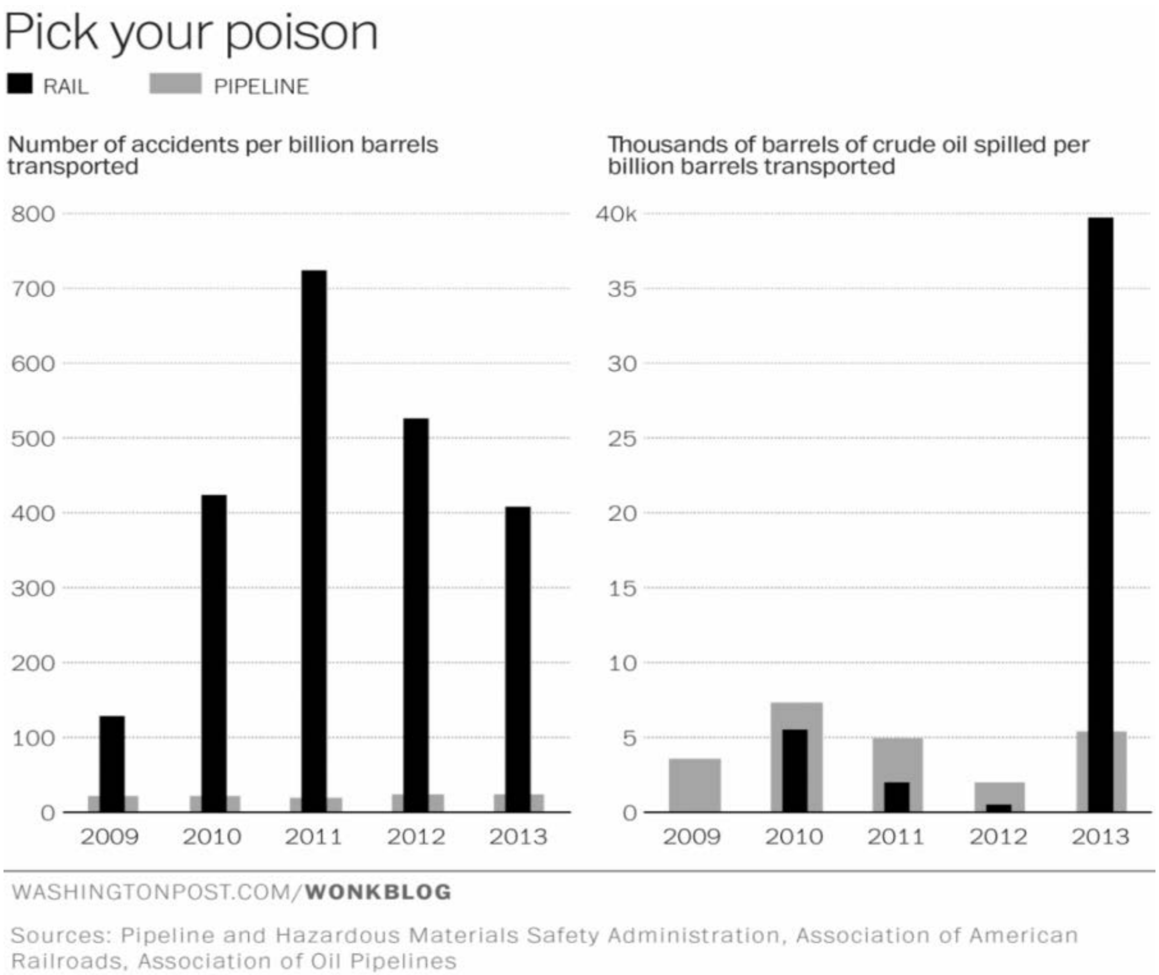
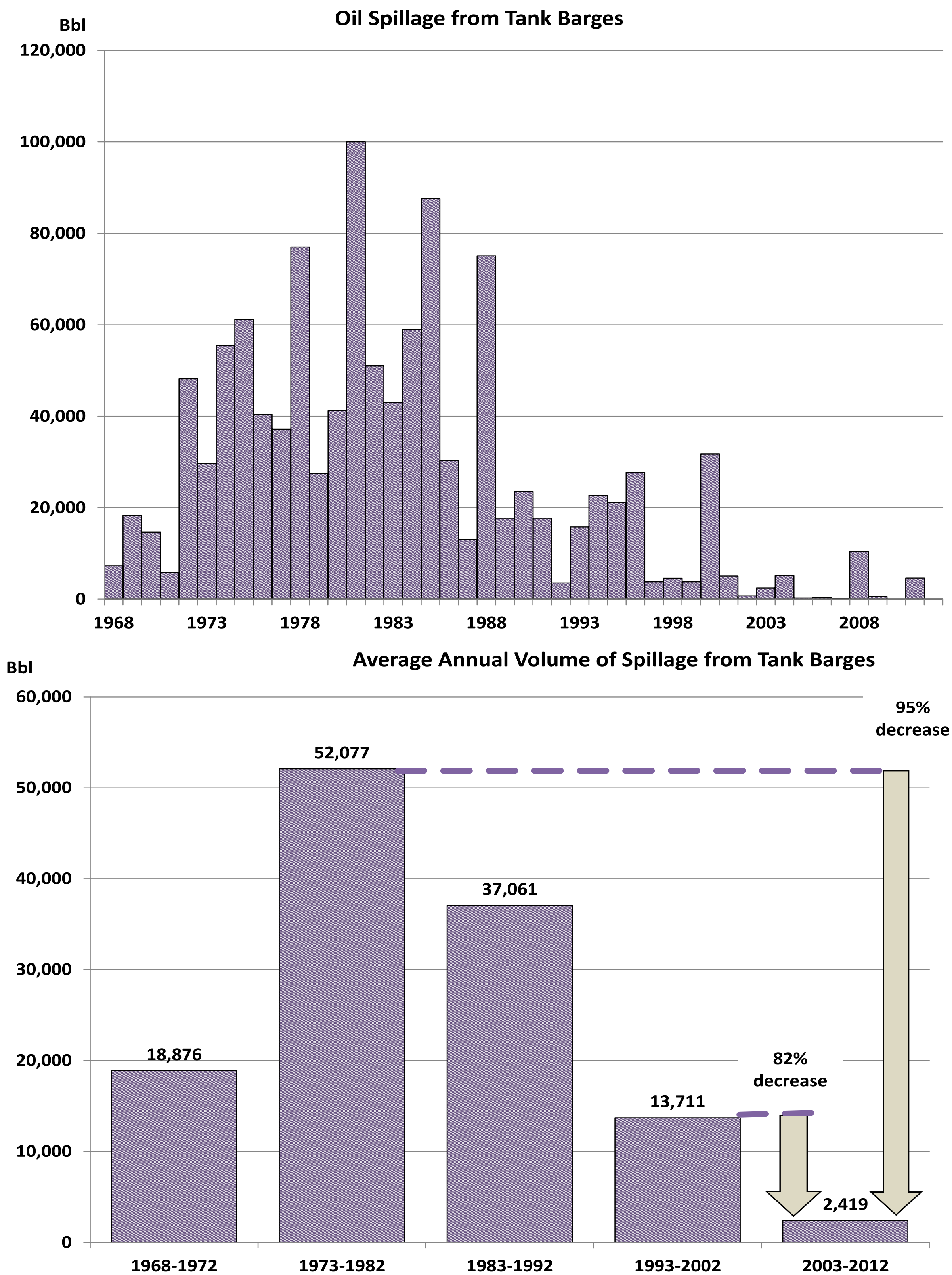


Figure 16. Rail and pipeline incidents per billion barrels transported between 2009 and 2013.

3.1.4 Tank Vessel/Waterways

Oil is also transported by tank barge, particularly in intra-coastal and inland waterways. Tank barges carrying oil as cargo spilled an average of 2,400 barrels of oil annually over the last decade. This volume represents an 82 percent reduction from the spillage in the previous decade.

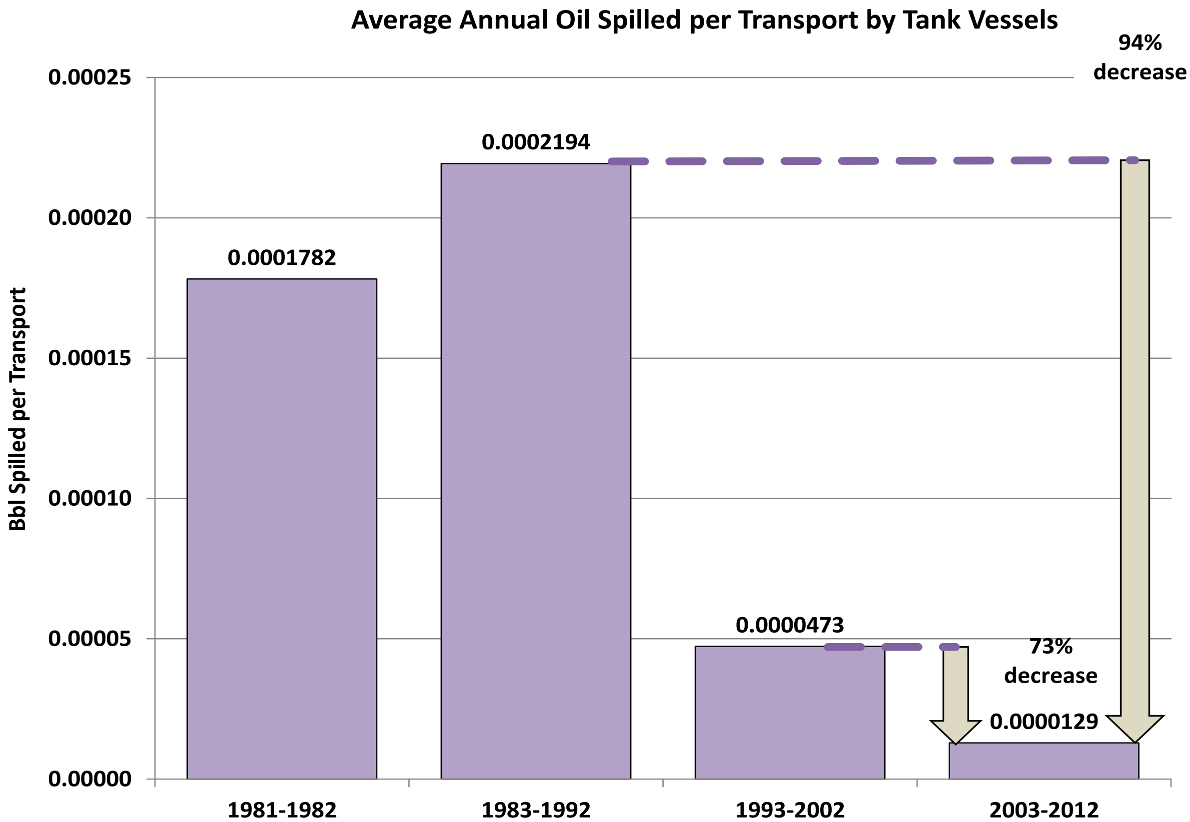
The two graphs in the following figure show a breakdown of annual spillage from oil tank barges (Etkin, 2014).



Source: (Etkin, 2014)

Figure 17. Oil spillage from tank barges.

The following figure shows annual oil spillage by both tankers and barges in U.S. waters (Etkin, 2014).



Source: (Etkin, 2014)

Figure 18. Oil spilled by tank vessels.

The infrastructure of marine transportation, other than the vessels themselves, would encompass the condition of the waterways and vessel traffic density.

The navigable waterways continually require dredging to maintain safe adequate clearance between vessel hulls and the channel bottom. Dredging of federally designated waterways is 100 percent funded by the Federal Government out of the Operation & Maintenance (O&M) budget of the Army Corps of Engineers. The maintenance of the Navigational Aids of these waterways is funded 100 percent by the Federal Government via the operational budget of the U.S. Coast Guard. The inland waterway lock system, also under the jurisdiction of the Army Corps of Engineers, is in continuing need of maintenance and repair to ensure safe, efficient navigation on those waterways that depend upon lock and dams to maintain navigability. With increasing potential for export of U.S. or Canadian crude, Liquefied Natural Gas (LNG), and Liquefied Hazardous Gas (LHG), marine traffic density in certain coastal ports may increase. This increase may have as a consequence more frequent marine incidents. The U.S. Coast Guard may need to recognize a requirement of increasing Vessel Traffic Systems (VTS) for ports that may see this increased traffic density.

Vessel spill statistics encompasses all oil types, e.g., clean refined petroleum products as well as heavy oils and crude. These figures verify that, over the decades, with improvement in the design of tank vessels—e.g., double hulls, voyage planning and crew training—oil spills from tank vessels are being significantly

reduced and thus, if OSP carriage by tank vessel within U.S. waters becomes more prevalent in the future, the incident rate would hopefully remain within the rates currently experienced.

3.1.5 Mitigating Risks of Oil Transport in Great Lakes Region

While some risks of oil transport in the Great Lakes region could be mitigated by construction of West-to-East and North-to-South pipelines, oil pipelines are long-term projects, expensive to construct, and with fixed routes. Railroads, barges, and trucks provide the transportation flexibility that oil industry shippers require to respond to changing trends in productivity at the resource extraction site and in demand from coastal refineries. So, although pipeline transport may be safer under some conditions, more flexible transport options are preferred for economic reasons. For example, while transport by rail is more expensive than by pipeline, transport time from production sites to coastal refineries is reduced from weeks to days. In addition to being economical, shortened transit time also reduces the risk of a catastrophic event since the shipped commodity spends less time in storage. However, each transport system has distinctive risks and impacts. In addition, the regulatory framework within which each transport network operates further complicates the problem of choice since it affects the way risks and impacts of a particular system are mitigated or addressed.

3.2 Role of Human Error

Human error plays a prominent role in many oil spill incidents showcased, resulting in more oil entering the environment than would have occurred if existing protocols had been properly followed. This situation was especially apparent in the Kalamazoo pipeline spill incident—the pipeline operators' inability to distinguish between false and real alarms, and the time delays involved in completely shutting down pipeline flow once anomalies were detected at the commencement of the incident. Thus, current pipeline operator preparedness and training requirements should be reviewed by federal pipeline regulators.

The National Transportation Safety Board determined that there was failure of Enbridge's control center staff to recognize abnormal conditions related to ruptures. Enbridge's leak detection and supervisory control and data acquisition systems generated alarms consistent with a ruptured pipeline on July 25 and July 26, 2010; however, the control center staff failed to recognize that the pipeline had ruptured until notified by an outside caller more than 17 hours later. During the July 25 shutdown, the control center staff attributed the alarms to the shutdown and interpreted them as indications of an incompletely filled pipeline (known as column separation). On July 26, the control center staff pumped additional oil into the ruptured pipeline for approximately 1.5 hours during two startups. The control center staff received many more leak detection alarms and noted large differences between the amount of oil being pumped into the pipeline and the amount being delivered, but the staff continued to attribute these conditions to column separation. An Enbridge supervisor had granted the control center staff permission to start up the pipeline for the third time just before they were notified about the release.

Human error will always occur and may be involved in the majority of accidents. However, the frequency of catastrophic outcomes could be reduced. To reduce such errors, all accidents need to be investigated for the role that human error played and procedures that could be instituted including: random inspection; practical exams; doubling of staff in critical circumstances; the use of specialized neural network decision algorithms to obviate inattentional blindness; initial and periodic refresher training. Updating current pipeline operator operational and preparedness training requirements is a way to handle these situations.

3.3 Health Risks

The diluents added to bitumen to create Dilbit contain alkanes; alkenes; benzene, toluene, ethylbenzene, and xylene (BTEX); and other chemicals that pose health risks to Dilbit spill responders. The following sections provide additional details of these health risks.

In recent years, Dilbit spills in Michigan (The Dilbit Disaster, 2014), Arkansas (Inside the Exxon Oil Spill in Arkansas, 2013), and elsewhere have provided convincing evidence on the subject; but researchers are still working on definitive scientific studies that would translate those examples into broader conclusions about the risks of Dilbit.

The 2010 spill could have been worse if it had reached Lake Michigan, as authorities originally feared it might. Lake Michigan supplies drinking water to more than 12 million people. Fortunately, the damage was restricted to a tributary creek and approximately 36 miles of the Kalamazoo, used primarily for recreation, not drinking water.

3.3.1 Adverse Health Effects from Kalamazoo River and Arkansas Incidents

The Dilbit that spilled in Michigan entered the Kalamazoo River, leading to the most expensive oil pipeline cleanup in U.S. history (now totaling more than $1 billion). After the spill in Michigan, the state Department of Public Health set up a broad surveillance effort that determined 320 people suffered adverse health effects, including cardiovascular, dermal, gastrointestinal, neurological, ocular, renal, and respiratory impacts.

Similarly, following the Arkansas spill, air monitoring data showed significantly increased levels of benzene in the ambient air; and residents living close to the spill reported increased headaches, nausea, and respiratory problems.

3.3.2 Evaporation of Diluent Fraction of OSP Mix

According to a 2013 NOAA report, responders to the Dilbit spill in Kalamazoo, MI, reported elevated levels of benzene in the air relative to those recorded at spills of standard crude oils (NOAA, 2013). Evaporation of diluent could pose an inhalation risk to responders and others in a spill-affected zone. The question of whether the diluent fraction of an OSP mix evaporates more rapidly than the lighter fractions of a typical crude oil remains open. The answer has important implications for responder safety and potential residential exposures, particularly under warm weather conditions.

3.3.3 Compositional Differences Between OSPs and Typical Crude Oils

It is not known whether other compositional differences between OSPs and typical crude oils affect risk levels for exposed people. For example, bitumen is characterized as being richer in sulfur than conventional oil (Zhou, Huang, & Liu, 2008), lower in mercury, and higher in lead content (Meyer, Attanasi, & Freeman, 2007).

There are no indications that these compositional differences result in increased risk during a spill. The diluent added to a mixture could potentially pose problems due to its low flash point; meaning combustion could be a problem from the evaporation of diluent. The MSDS for ConocoPhillips (2012) and Gibsons (2012) natural gas condensate lists the product as extremely flammable. ConocoPhillips (2012) further

warns that condensate is toxic and potentially fatal if inhaled resulting from the hydrogen sulfide gas content. The MSDS for Hess (2012) lists sweet natural gas condensate as only marginally toxic through inhalation probably because of lower hydrogen sulfide levels (ConocoPhillips, 2012) (Gibsons, 2012) (Hess, 2012).

Benzene, a known carcinogen, is also present in natural gas condensate. Benzene could pose a risk to spill responders. The MSDS for Hess (2012), ConocoPhillips (2012), and Gibsons (2012) recommend spill responders wear air supplied respirators, protective clothing, and eye protection. The MSDS for natural gas condensate for Oneok (2009) warns that condensate, being denser than air, will accumulate in depressions. These MSDS recommendations and warnings are for natural gas condensate alone; the risks from natural gas condensate after blending to form Dilbit would be expected to be different; thus, MSDS need to be specific pursuant to various blends and should be updated accordingly and be promptly available to responders in the initial stages of a spill response (Oneok, 2009).

3.3.4 Risk created by Alberta Crude Oil Blends during Spills

The USCG Gulf Strike Team issued a Hazard Awareness bulletin concerning Canadian Tar Sands Oil, Hazard Awareness. In this excerpt from the bulletin, the U.S. Coast Guard states (U.S. Coast Guard, 2014):

> *"Diluents, a fluid used to lower viscosity, are added to bitumen based oils (Tar Sands Oil) in large enough quantities to make the original product easier to pump and transport. A diluent frequently used in large volume is Natural Gas Condensate. Natural Gas Condensate consists of many short chain hydrocarbons, which include various alkanes, alkenes, BTEX (Benzene, Tolulene, Ethyl Benzene, Xylenes), and longer single chain chemical variants. Natural Gas Condensate can have a proper shipping name of Petroleum Distillates, N.O.S., which is classified as a dangerous good under the IMDG Code. Some of the hazards include: flammability; easily ignited by heat, sparks or flames; vapors forming explosive mixtures with air; toxicity through various routes of exposure; and being volatile at room temperature. Once the diluent is separated from the product, the original physical properties of the bitumen return which emulate characteristics of roofing tar. In a marine or aquatic environment, and under the right conditions, this dense product could sink to the bottom of the impacted waterway making recovery efforts far more challenging and time consuming than traditional recovery techniques."*

The U.S. Coast Guard provides steps to Protect Responders in the following excerpt from the Gulf Strike Team bulletin (U.S. Coast Guard, 2014):

> *"VOCs, including BTEX, can pose a direct hazard to the health of responders. Each type of oil presented above is acknowledged to contain these compounds, which during a response, present at a minimum an inhalation hazard to responders. One way to mitigate this hazard is to have the appropriate detection capabilities deployed to properly identify and quantify the hazard prior to impacting response personnel. Once quantified, appropriate personnel protective strategies can be implemented, such as the wearing of an air purifying respirator or self-contained breathing apparatus. Special air monitoring equipment may be required to properly identify BTEX hazards. Should a response event involve any of the above discussed oils, ensure that appropriate equipment is a part of the planning phase of a deployment to alert responders to a potential hazard."*

Table 6 demonstrates the substantial fraction of BTEX contained in the various Alberta crude blends. The table shows examples of the chemical properties of various Alberta crude blends (Polaris Applied Sciences, 2013).

The Physicians for Social Responsibility website (psr.org, n.d.) states that benzene and toluene pose short-term and long-term health hazards to people working with these chemicals and the potential for health effects when a spill occurs. Benzene and toluene are highly volatile; so most exposures occur through inhalation causing headache, dizziness, drowsiness, confusion, tremors, and loss of consciousness. They can also cause eye and skin irritation through exposure to the vapors. These chemicals can also be ingested through the skin upon direct surface exposure.

Table 6. Ranges of select chemical properties (volume percent) for example Alberta crude oil blends.

Component	Mixed Sweet Blend (MSW)	Husky Synthetic Blend (HSB)	Premium Albian Synthetic (PAS)	Lloyd Kerrobert (LLK)	Wabasca Heavy (WH)	Western Canadian Blend (WCB)	Access Western Blend (AWB)	Cold Lake (CL)	Western Canadian Select (WCS)	Albian Heavy Synthetic (AHS)
Benzene	0.27 ± 0.05	0.04 ± 0.01	0.03 ± 0.01	0.14 ± 0.05	0.12 ± 0.02	0.10 ± 0.03	0.29 ± 0.03	0.23 ± 0.03	0.16 ± 0.03	0.15 ± 0.03
Toluene	0.81 ± 0.13	0.15 ± 0.03	0.21 ± 0.07	0.21 ± 0.08	0.29 ± 0.07	0.18 ± 0.04	0.50 ± 0.08	0.39 ± 0.07	0.30 ± 0.06	0.37 ± 0.09
Ethyl Benzene	0.24 ± 0.03	0.10 ± 0.02	0.16 ± 0.03	0.04 ± 0.01	0.13 ± 0.02	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.12 ± 0.03
Xylenes	1.06 ± 0.13	0.33 ± 0.05	0.54 ± 0.16	0.19 ± 0.06	0.47 ± 0.10	0.25 ± 0.04	0.39 ± 0.08	0.33 ± 0.07	0.29 ± 0.06	0.43 ± 0.12
Butanes	3.86 ± 0.62	2.32 ± 0.74	0.24 ± 0.45	1.75 ± 0.36	1.73 ± 0.34	0.62 ± 0.12	0.68 ± 0.15	1.02 ± 0.25	2.02 ± 0.39	1.50 ± 0.33
Pentanes	3.35 ± 0.58	1.61 ± 0.34	0.41 ± 0.27	5.57 ± 0.92	2.70 ± 0.79	3.72 ± 0.76	8.42 ± 1.21	6.18 ± 0.99	4.36 ± 0.81	4.66 ± 1.19
Hexanes	5.68 ± 0.55	2.02 ± 0.31	1.04 ± 0.29	3.19 ± 0.84	3.07 ± 0.37	3.11 ± 0.47	6.81 ± 0.67	5.31 ± 0.64	3.90 ± 0.54	5.10 ± 0.66
Heptanes	7.05 ± 0.57	2.03 ± 0.27	1.75 ± 0.34	2.07 ± 0.51	2.95 ± 0.40	2.51 ± 0.29	4.35 ± 0.49	3.36 ± 0.47	2.80 ± 0.43	3.81 ± 0.55
Octanes	7.10 ± 0.60	2.73 ± 0.34	3.31 ± 0.55	1.48 ± 0.35	3.01 ± 0.54	2.13 ± 0.22	2.57 ± 0.44	2.23 ± 0.43	2.11 ± 0.37	3.30 ± 0.64
Nonanes	5.51 ± 0.46	2.43 ± 0.31	3.96 ± 0.62	1.20 ± 0.29	2.50 ± 0.49	1.84 ± 0.31	1.25 ± 0.24	1.35 ± 0.31	1.49 ± 0.31	2.08 ± 0.51
Decanes	2.49 ± 0.26	1.29 ± 0.17	2.35 ± 0.40	0.59 ± 0.19	1.13 ± 0.28	0.88 ± 0.25	0.54 ± 0.12	0.63 ± 0.18	0.71 ± 0.16	0.93 ± 0.24

Source: CrudeMonitor (2013) - 5-yr average and range

Chronic exposure to benzene has been linked to a number of leukemia cases in adults and children (acute myeloid leukemia, acute and chronic lymphocytic leukemia), non-Hodgkin's lymphoma, multiple myeloma, and aplastic anemia. It also has been linked to immune system effects reducing resistance to infection. Over time, benzene exposure can also cause reproductive problems including abnormal sperm in men, and irregular periods and smaller ovaries in women. It has also been linked to low birth weight.

In a 2013 Inside Climate News article concerning public health issues that may arise in a tar sands oil spill relating to air, Lisa Song states (Song, 2013):

> *"The federal Agency for Toxic Substances and Disease Registry (ATSDR), for instance, estimates that people can be exposed to air containing 9 parts per million (ppm) of benzene for up to two weeks, or 6 ppm for up to a year, without a "likely" increase in harmful health effects. But those guidelines don't cover the risk of cancer, and they are "not intended to define clean up or action levels for ATSDR or other Agencies," according to ATSDR's website."*

The Physicians for Social Responsibility website (psr.org, n.d.) advises that toxicologists must recognize that exposures to a mixture of volatile organic compounds can result in synergistic effects that exacerbate the adverse health effects of the individual chemicals. Long-term exposure to toluene may harm the nervous system, heart, liver, and kidneys. Nervous system effects include reductions in thinking, memory, and muscular abilities. It can also cause hearing loss and color vision loss. At very high levels, toluene can cause permanent toxicity to the brain. It has also been associated with low birth weight. There is a burgeoning recognition of the severe and adverse health effects associated with exposure to BTEX. For example, following the Enbridge spill in Kalamazoo, MI, 320 community members and 11 spill responders reported adverse health effects, which included headaches, nausea, and respiratory issues (Michigan Dept. of Community Health, 2010) (NOAA, 2013). In the days following the Kalamazoo spill, authorities advised local residents within approximately one mile of the river to remain indoors or leave the area to limit their exposure to toxic fumes. Specific information about the diluent added to an oil sands mixture of concern would be key to more accurately determining risk to responders and nearby human communities.

The Michigan Department of Health produced a list and statistical breakdown of the observed adverse health effects. In response to concerns about acute health effects from exposure to spilled oil in this major oil spill, state and local public health officials in Michigan quickly set up a multi-faceted public health surveillance system that included health care provider reporting, community surveys, calls from the public to the Poison Control Center, and analysis of data submitted to the state's syndromic surveillance system (Michigan Dept. of Community Health, 2010). The surveillance system received 147 health care provider reports on 145 patients, identified 320 (58 percent) of 550 individuals with adverse health effects from four community surveys along the impacted waterways, identified one small worksite with symptomatic employees, and tracked 41 calls that were placed to the poison center by the public. Headache, nausea, and respiratory symptoms were the predominant symptoms reported by exposed individuals in all reporting systems. These symptoms are consistent with the published literature regarding potential health effects associated with acute exposure to crude oil.

One should also be cognizant that municipalities use many inland fresh water waterways as their source of potable drinking water. This situation can be understood from a nominal calculation regarding the recent event when a ruptured oil pipeline leaked up to 40,000 gallons of crude, which is believed to have been

Bakken crude, into the Yellowstone River in Montana in January 2015; and contaminated the drinking water for the nearby town of Glendive, Montana.

When approximate concentration values are used for BTEX concentrations in spilled crude, the scale and potential hazards of the public's exposure is readily apparent. The calculations in the next section are simplistic. Precise calculations require an ongoing research project to actually measure the concentrations of contaminants in the drinking water downstream of a flowing river at various locations and times for exact modeling. It is an additional recommendation of this report that following all future spills where drinking water supplies are at risk, sampling by position and time subsequent to the spill including at water ingestion locations for municipal supplies should be performed and submitted to rigorous scientific analysis.

For example, assume that the flow rate of the Yellowstone River is nominally 190 m^3/s near Glendive, MT. Assume also that the 2015 spill consisted of 50,000 gallons of oil being spilled into the Yellowstone River. BTEX are found at approximately 4 g / l in crude oil (this figure will vary depending on the source of the Dilbit, the nature of the diluents, etc., but is fairly close to the correct figure). Therefore, the Yellowstone spill would have spilled nominally 800,000 g of BTEX into the water supply. We shall assume that this level is close to the level of benzene spilled (although the toxicity levels of each of the components ethyl benzene, toluene, and xylene, differs somewhat from that of Benzene). We shall also assume that all the BTEX in the oil ended up dissolved in the water. This latter assumption is not quite right because some BTEX will remain dissolved in the denser components, depending on the amount of turbulence, and some BTEX will evaporate into the surrounding atmosphere. Nevertheless, if this latter caveat is lifted, it can be determined that enough benzene was released by the spill to raise to the maximum contaminant level (MCL) value a volume of water equivalent to 1.6×10^{11} Liters. There are 10^3 L / m^3. Therefore, the contaminated volume would be approximately 1.6×10^8 m^3. This volume corresponds to every drop of water from that river flowing past the contamination site for 842,000 seconds or 234 hours, i.e., approximately 10 days. Any residents consuming water from that river during that time period very likely could have been exposed to carcinogen levels in excess of EPA mandated MCL values for at least 10 days after the spill.

Since some of these carcinogens will have adsorbed onto solid sediments in the river, it is very likely that there will be relatively high levels of contamination in the water for longer than 10 days. Thus, it is the specific recommendation of this report that when a spill contaminates a drinking water supply, affected residents should not be permitted to consume water in this example until ingested water is chemically tested to be at safe levels. A boil order is inadequate since this will not remove a substantial fraction of the dissolved carcinogens and toxins. The boil order is more appropriate for a biological spill rather than a chemical spill. Furthermore, the local water mains distribution hubs should be tested for safety levels of contamination. Finally, the residents should be instructed on how to flush their pipes to remove any last-mile contamination.

3.4 Environmental Risks

If an oil spill occurs, its impacts would depend on multiple factors, including the type, volume, and location of the oil spill. Although location is generally considered the most important factor; spills of OSPs (e.g., Dilbit) may result in different impacts than spills of other crude oils. Although parallels may be drawn between the possible behavior of conventional crudes and Dilbit, definitive studies appear to be scarce regarding spills of heavy crudes with the specific composition of Canadian heavy crudes.

In estimating potential environmental impacts, several factors will be important, including the size and location of the release, leak, or spill, and how quickly it is remediated. An oil spill on land would not necessarily result in surface or groundwater contamination. The potential for a spill to reach water would depend on factors such as its proximity to a water source (e.g., on or near a creek or stream or located on land where the groundwater table is close to the surface), the characteristics of the environment into which the crude oil is released (e.g., porous underlying soils), the volume of the spill, its duration, and the viscosity and density of the crude oil involved.

3.4.1 Studies on Behavior of Crude Oil Spills

The behavior of crude oil spills and its fate in the subsurface have been studied extensively around the world for a wide range of conventional crudes and other petrochemicals in both experimental settings and actual spills (e.g., Bemidji, Minnesota in 1979). These studies include studies of specific chemical components that may be present in Dilbit, e.g., benzene. Based on extensive experience with other crudes and Dilbit constituents, analysts may claim considerable confidence in models of Dilbit behavior in groundwater. For example, the Canadian Energy Resources Conservation Board has stated that *"Dilbit should behave in much the same manner as other crude oils of similar characteristics."* (Ramseur, et al., 2014).

3.4.2 Difficulty of Removing Denser Components of a Dilbit Spill

The denser components of a Dilbit spill would be difficult to remove from the soil during cleanup operations, and may require wholesale soil removal instead of other remediation techniques. During the Kalamazoo River spill in Michigan in 2010, removal of the heavier components from vegetation alongside the river bank was extremely difficult and, thus, remediation consisted of removing the contaminated vegetation. The 2014 Keystone XL Environmental Impact Statement (EIS) states that Dilbit intermixed with sediment and trapped in the river bed and shoreline results in a persistent source of oil and has the potential to present additional response and recovery challenges (U.S. Dept. of State, 2014). These challenges may come at a higher cost. In an oil spill model prepared for the EPA, the model estimates that spills of heavy crude will cost nearly twice as much to clean up as comparable spills of conventional crude oil.

3.4.3 Weathering of Spilled Oil

All spilled oil begins to weather or separate into different components over time. For a land spill, the heavier and more viscous components (i.e., the asphaltenes) would likely remain trapped in soil pores above the water table. It is also likely that the lighter constituents would partly evaporate and not be transported down through the soil with the heavier components. However, if an oil spill reached the water table; some of the more soluble portions would likely dissolve into the groundwater and be transported in the direction of regional groundwater flow. The ultimate extent, shape, and composition of a groundwater contaminant plume resulting from a Dilbit spill would depend on the specific characteristics of the soil, aquifer, and the amount and duration of the accidental release.

3.4.4 EPA Concerns Over Potential Impacts from Pipeline Leaks

In the U.S. EPA's Letter to the U.S. Department of State dated July 16, 2010 on the draft EIS for the Keystone XL Project, EPA expressed particular concern over the potential adverse impacts to surface and ground water from pipeline leaks or spills. That concern stemmed from two areas—the toxicity of chemical

diluents that may be used and the lack of risk assessment for potential serious or significant spills, including an evaluation of spill response procedures in the wake of such a spill. (EPA, 2010)

Concerns reflected in EPA's letter were realized 10 days later when the Enbridge Energy Partners' Alberta Pipeline ruptured near Marshall, MI. The resulting spill released crude into a tributary creek of the Kalamazoo River and traveled approximately 40 miles downstream in the Kalamazoo River. Initially estimated by Enbridge as a release of approximately 840,000 gallons of crude, EPA subsequently estimated that over 1.1 million gallons were released.

After the spill, public access to 39 miles of the river system was banned to protect public health and safety. In March 2013, the EPA ordered Enbridge to implement containment and dredging of submerged oil to prevent continued migration of oil downstream to the Kalamazoo River; the remediation activity ended in August of 2014.

Steve Hamilton, a professor of ecosystem ecology and biogeochemistry at Michigan State University, advised the U.S. Environmental Protection Agency and Enbridge on the Kalamazoo spill. Because the river was high, the bitumen eventually coated a vast expanse of land as the water dropped. *"The only way to get it off was to harvest all the vegetation and scrape the soil,"* Hamilton said. At one point, the enterprise occupied more than 2,000 workers. *"People literally were going in with shovels and clippers and plastic bags collecting all this stuff."* Detergents were ineffective, Hamilton said (Schulte, 2013).

3.4.5 Lack of Knowledge in Response to Dilbit Spills

A paper by Jessica Winter and Robert Haddad of the NOAA Office of Response and Restoration, concluded: (NOAA Office of Response and Restoration, 2014b)

> *"Although Dilbit is not a new product, our knowledge of how to respond to Dilbit spills is still in its infancy and cleanup tactics for Dilbit are fairly experimental: U.S. EPA stated that they were "writing the book" on Dilbit spill response at the Enbridge 2010 spill (Klug, 2011). There is little information available on how sediment agitation and similar tactics affect the environment and how those impacts compare to the toxicity of the oil. Acute toxicity tests conducted at the Enbridge spill found that the weathered Dilbit in Kalamazoo River sediments collected in February 2012 (1.5 years after the spill) was not significantly toxic. However, chronic toxicity tests have yet to be completed (Great Lakes Environmental Center, 2012). More toxicity studies and further assessment of the effects of cleanup-related physical disturbances are needed to appropriately balance the cleanup with natural recovery.*
>
> *Meanwhile, Dilbit's mixture of heavy and light components makes it highly susceptible to weathering-induced changes, making it difficult to predict whether and when it will sink. This requires more samples in more media to track the fate of the oil, compared to other oils that better fit existing predictive models. Overall, Dilbit behavior does not fit well into existing paradigms for oil, and thus basic data are needed to guide future work."*

4 CONCLUSIONS AND RECOMMENDATIONS

The following discussion raises issues that were contained within this analysis as well as various primary sources (NOAA, 2013) (NTSB, 2012) (Ramseur, 2015).

4.1 Oil Spill Response Plans (OSRPs)

Oil Spill Response Plans (OSRPs) are not consistently integrated with the regional and area contingency planning process. One of the requirements for PHMSA pipeline contingency plans is to ensure consistency with area, regional, and national contingency plans. However, a reported lack of coordination between Regional Response Team (RRTs) and PHMSA, as pointed out in the NOAA technical memorandum NOS OR&R 44 (NOAA, 2013), raises the concern that the PHMSA plans are not integrated into regional and area plans and vice versa. The fact that RRTs might not have access to plans and cannot integrate them accordingly into their plans, could result in inconsistencies between plans and a compromised response effort in the case of a spill. Pipeline and railroad response planning must be consistent with the ACP.

ACPs that have Dilbit being transported or stored in their area of responsibility usually do not have oil spill scenarios involving submerged oils. Geographic Response Plans (GRP) of the ACPs, do not usually include submerged oil response information. Since Dilbit is not classed as a Group 5 oil, the OSRPs of plan holders transporting Dilbit do not require the OSRPs to contain preparedness and response strategies and tactics to respond to the portion of Dilbit that may submerge beneath the surface. No contracted resources for submerged oil are required in an OSRP for movements of Dilbit. There is no current requirement to promptly advise responders that the materials being transported or spilled is other than heavy crude oil.

USCG Vessel Response requirements are listed in 33 CFR 155.1052: Response plan development and evaluation criteria for vessels carrying group V petroleum oil as a primary cargo: (33 CFR 155.1052, 2011)

> *(a) Owners and operators of vessels that carry group V petroleum oil as a primary cargo must provide information in their plan that identifies—*
>
> > *(1) Procedures and strategies for responding to discharges up to a worst case discharge of group V petroleum oils to the maximum extent practicable; and*
> >
> > *(2) Sources of the equipment and supplies necessary to locate, recover, and mitigate such a discharge.*
>
> *(c) The owner or operator of a vessel carrying group V petroleum oil as a primary cargo must identify in the response plan and ensure, through contract or other approved means, the availability of required equipment, including—*
>
> > *(1) Sonar, sampling equipment, or other methods for locating the oil on the bottom or suspended in the water column;*
> >
> > *(2) Containment boom, sorbent boom, silt curtains, or other methods for containing oil that may remain floating on the surface or to reduce spreading on the bottom;*
> >
> > *(3) Dredges, pumps, or other equipment necessary to recover oil from the bottom and shoreline; and*

(4) Other appropriate equipment necessary to respond to a discharge involving the type of oil carried.

Recommendation:

The Coast Guard should continue to encourage RRTs to cooperate with PHMSA and FRA to increase coordination of oil spill plans, particularly as they relate to OSPs. The National Response Team (NRT) could facilitate conversations at the federal level to promote national consistency and clarity with respect to the roles and obligations of agencies in spill response planning.

The Coast Guard should consider a means for addressing submerged oils which may be present in surface water spills that can be included in GRPs and ACPs. For Group V oils or ***oils that may exhibit similar qualities when discharged into the environment***, the U.S. Coast Guard should consider a of review current oil spill response plan requirements for vessels and facilities; revise regulations to reflect specific preparedness requirements; revise regulations for response resources in specific types, quantities, and operational parameters; and revise regulations for on-scene arrival time frames of specific response resources. These revisions are needed because current plan requirements are very generic and should be much more specific in the type and quantity to ensure that resources specified are effective and available within the appropriate tiered response time frame.

The process of USCG classification of Oil Spill Response Organizations (OSROs) as Group V capable should be reviewed as to the adequacy of the evaluation process in ensuring OSROs have sufficient and effective planned response resource capability and training. Quantification, specificity, and effectiveness of the response resources for Group V oils, or oils that may exhibit similar qualities when discharged into the environment, must be part of that classification process.

4.2 Human Health and Safety Impacts of OSPs

The NOAA Technical Memorandum, NOS OR&R 44, dated September 2013, points out that there are important gaps in information related to human health impacts of OSPs during spills and spill responses, which largely center on the composition of the diluent components of the mixture and uncertainties regarding the behavior of the diluent in the environment (NOAA, 2013).

More information is necessary to understand whether OSP blends weather differently from comparable crude oils. Specifically, it is not known whether the diluent portion of an oil sands mixture has significantly different evaporation kinetics than the light fractions of a crude oil.

It is possible that the evaporated diluent component of an oil sands mixture could present a higher explosive risk than would be expected for crude oils, although it should be noted that many crude oils contain a relatively high proportion of volatile chemicals with low flash point.

Lack of information causes confusion and delays decision making by local authorities as to the flammability of the material and toxic emissions of the product to ensure safe and effective responses by first responders and potential evacuation orders for the public.

Recommendation:

Specific information about the diluent added to an oil sands mixture of concern would be key to determine more accurately the risk to responders and nearby human communities. This information would be vital and

should be more available. This information is needed for responders to be aware of the necessary level of personal protective equipment (PPE), including respiratory protection, that they should be prepared to use; and for public health and safety, concerning guidance for jurisdictional authorities to base evacuation and reentry planning for residents, who may be in danger from toxic fume exposures.

4.3 Training and Equipping of First Responders

Although not the Coast Guard's direct responsibility, training and equipping appears to be inadequate for first responders (local and state municipalities) and OSROs (CG responsibility), who manage the initial stages of response to a tank car, pipeline, or bulk storage terminal incident. Mobile fire suppression systems—including foam capability, fully trained and equipped fire department Hazardous Material Teams, and the ability to monitor potential toxic fume emissions to enable prompt decision making about first responder and public health and safety—may be of insufficient quantity to promptly respond to a catastrophic rail or pipeline incident.

Recommendation:

The Coast Guard should continue to assist other agencies and states for training and equipment of first responders as needed because of the CG institutional knowledge. The CG should consider evaluating the requirements for OSROs' need to ensure a safe and effective response to spills, fire or explosion events, and toxic emissions that may lead to evacuations. Improved content and faster information sharing is necessary to provide to first responders and OSROs for safe and effective responses, which includes the need to provide MSDSs relevant to various bitumen blends addressing fire, explosion, health impacts, etc.

4.4 Physical and Chemical Properties and Processes of OSPs

The NOAA Technical Memorandum NOS OR&R 44 found that information on the physical properties of Alberta OSPs can be challenging, as some of the data for specific physical and chemical properties are considered to be proprietary business information (NOAA, 2013). Physical properties of oil sands-derived products fluctuate based on season, customer requirements, and other factors. For this reason, it has been difficult for regulators and others in the scientific community to access and predict physical behavior in the environment. The API densities listed on the commonly referenced Environment Canada website may be out of date or incomplete. These values should be reviewed and, as needed, updated to provide a more comprehensive knowledge base for modeling the environmental fate and behavior of OSPs.

The physical properties and behavior of the diluent component of oil sands mixtures, and the associated potential public health concerns have not been adequately addressed. Lack of diluent information, as to type and volume percentage, for a specific OSP can cause potential public and responder health risks and impact cleanup activities. Regulatory and response agencies and contractors are not likely to have sufficient information about what product is being transported through a pipeline at any given time. The lag time associated with getting accurate data from the producer or pipeline operator may impede attempts to assess likely behavior and effects. This situation will result in delays to the response and cleanup efforts.

The lack of experimental data on the weathering behavior of OSPs limits the ability of spill response organizations to understand and predict the behavior and fate of OSPs in freshwater, estuarine, and saltwater environments. There are uncertainties regarding how weathering affects the environmental fate and behavior of spilled OSPs, particularly under differing conditions of salinity and temperature. That is, what are the conditions, if any, under which spilled OSPs would be over-washed by water, suspended in the water

column, or submerged and laying on the bottom of the waterway. The Kalamazoo spill also witnessed the inability to remove the bitumen from vegetation once the light components evaporated, thus requiring significant removal of vegetation to remediate the area.

The NOAA technical memorandum advises that the Kalamazoo spill illustrated how weathering and sedimentation may lead to the oil being over-washed by water, suspended in the water column, or sinking to the bottom. There is a gap in understanding how OSPs are affected by the weathering and sedimentation processes and also the time frame when these processes. A better understanding of the physical processes involved will greatly aid the success of spill response.

Recommendation:

The Coast Guard should work with industry and other US and Canadian agencies to have sufficient information on the MSDS that is specific for each blended bitumen product, versus a generic MSDS that encapsulates all blends as if they were similar in characteristics and having similar proportions of various components of the material. Each bitumen blend should have an MSDS for the specific characteristics of that blend showing the percentage of the diluent, the chemical components of the diluent, flammability, hazard, and health information specific for that blend

Various bitumen blends may act differently in the environment and may pose differing environmental, safety and health issues to responders and the public. Further research is necessary for each bitumen blend to assess likely behavior and effects. The Coast Guard should cooperate with other Federal and Canadian agencies to better understand the weathering effects of various bitumen blends in differing environmental conditions to determine environmental impacts of a spill and potential effective response techniques.

4.5 Response Gap for Non-Floating Oils

The NOAA technical memorandum evaluated three case studies of actual oil sands spills: the Kalamazoo, Michigan; the Burnaby Harbor; and the Wabamun Lake spill. Each of these spills illustrated the ineffectiveness of management during the spill response. It appears that the current plans, training procedures, and equipment resources are not sufficient to prevent amounts of oil from entering the natural environment or to remove once a portion of the spilled material submerges. It should be noted that OSP spills have occurred in relatively shallow waterways. A spill in much deeper water with differing temperature thermoclines—which may have steep temperature gradients in a body of water, such as one of the Great Lakes, marked by a layer above and below which the water is at different temperatures—is not understood as to what may occur if the material submerges: a plume mid-depth or settling on the bottom. If the materials settle in the sediment of a deep-depth water body, what are the removal technique differences between what occurred on the Kalzmazoo River having depths of 5 to 15 feet and the greater depths of the Great Lakes?

4.5.1 Dilbit Classification

There is a concern that, in certain scenarios, OSPs could have the characteristics of Group V (or non-floating) oils. Oil sands-derived products are normally classified as Group III or IV oils so the contingency planning requirements for Group V oils, therefore, do not apply to oil sands-derived products. However, as diluents weather after a Dilbit spill or if unblended bitumen were to be transported via tank car, the material at the spill site could potentially be a non-floating oil. In failing to suggest that bitumen-products could potentially meet the characteristics of Group V oils, contingency plans and regulatory requirements could be

underestimating the risks and response needs in the case of a spill of OSPs. Response plans do not address the potential for OSPs to act as non-floating oils in the case of spill. OSRPs treat oil sands as a Group III floating oil and only require the Responsible Party to prepare for floating oil response and to contract with oil spill response organizations that do not have Group V oil capabilities.

When an oil spill occurs, the Responsible Party must respond within a specific period of time. If there is an OSP spill, the Responsible Party will be in compliance with oil spill response requirements as long as they have personnel on the site performing recovery efforts (e.g. divers), not necessarily with the appropriate equipment to the specific type of oil spilled. This situation could mean that the Responsible Party would have to wait up to 72 hours for the appropriate equipment to reach the site if the spill is in Washington but the needed equipment is in Detroit or Houston.

Recommendation

The Coast Guard should reconsider the classification of Dilbit to account for the characteristics of the spilled material after it enters the environment and not just its characteristics prior to its release. Perhaps a reclassification of blended bitumen should be considered similar to *"for Group V oils or* ***oils that may exhibit similar qualities when discharged into the environment"***. Current requirements are very general as to type of equipment and time to arrive on site for specific equipment. Effectiveness of equipment and operator training are not specifically addressed. OSRO's abilities to provide the necessary resources should be evaluated as to USCG classification. It is recommended that a stakeholder workshop be conducted on this entire issue to gain the perspective of Responsible Parties, OSROs, Federal and State jurisdictional agencies to consider a policy or regulation revision.

4.5.2 Need for Additional FOSC and Responder Information

Additional FOSC and responder information sources are needed for both offshore and nearshore/onshore geographic areas for responses to submerged oils. Prompt communication of the potential for sinking oil must be brought to the attention of the FOSC/Unified Command. The difficulty in ramping up operations to detect and recover submerged oils in the water column or on the sea bottom is no small logistical/operational matter; thus, it is necessary to commence preparations for, and response to, the potential for submerged oil as soon as feasible.

There are multiple information gaps in policy and research in terms of equipment and mandated response capacity:

- Clean up regulations require oil cooperatives to prove that they possess the equipment and can respond to a spill during a specified time period. However, policy does not require them to demonstrate the effectiveness of the equipment on specific oils, which may affect oil spill response effectiveness.
- Improvement and additional research is needed in developing information and the ability to employ oil spill detection and recovery methods specifically to address the portion of the oil that submerges and becomes either suspended in the water column or lies on or becomes entrained in the sediment at the bottom of a water body.

Table 7. FOSC information needs for dilbit spills.

FOSC Information Needs for Dilbit Spills
Prompt Guidance by Responsible Party on spilled Dilbit.
Determination of current environmental conditions that may foster the potential for Dilbit to submerge.
Where are the detection, tracking, containment, and recovery resources for submerged oil/Dilbit response located?
What are specific types and quantities of those submerged oil/Dilbit spill response resources that are available?
Are those available response resources effective on submerged oils/Dilbit in fresh and/or salt water spills?
Are those response resources capable of sustained effective response operations in offshore and/or nearshore geographic areas?
Are those response resources effective at the range of water depths, current velocities and underwater visibilities that may be encountered in offshore or nearshore waters?
How long will it take for those response resources accompanied by trained operational personnel to arrive on site to commence response operations?
Protocols for the use of chemical treating agents and shoreline remediation.
Protocols for the use of chemical treating agents and surface application of dispersants (Exclude Great Lakes).
Guidebook for responder and public health and safety for OSP spills.
Submerged Oil Response Guidance (based upon RDC Development of Bottom Oil Recovery Systems - Final Project Report-June 2013) included in ACPs.
Completed GRPs for submerged oils, including natural collection sites, e.g., pools above dam structures, where the flow velocity decreases and submerged oil may settle and collect on the bottom.
Updated version of API Publication #4558, “Options for Minimizing Environmental Impacts of Freshwater Spill Response”.
Submerged Oil Trajectory Modeling Tool.
Guidelines for protection of water intakes during spills of submerged oil and the restarting of water systems to ensure safe drinking water.
Rapid-assessment protocols to determine impacts of submerged oil spills.

At this time, the above information needs would not be immediately available to an EPA or USCG FOSC, due to lack of regulatory requirements, lack of information in ACPs and GRPs, and insufficient information concerning each of those needed criteria. The information in the ACP and GRP should include the identification of vulnerable locations near possible water, rail and pipeline transportation routes; including:

- Human infrastructure;
- Ecologically significant communities, sensitive species, and habitats, and sensitive shorelines;
- And response requirements: access, and pre-selection of appropriate response options.

Recommendation:

There are substantial informational needs that should be developed to assist the FOSC in preparing for, and responding to, Dilbit spills in nearshore/onshore and offshore geographic environments with regards to the fate and effect of Dilbit. The information should include predicting the transportation of Dilbit in the water column or on the bottom; public and responder health and safety; protocols for the use of chemical agents; drinking water intake protections; and submerged oil response guidance in strategies, tactics, and appropriate utilization of equipment types and quantities for optimal response decision making.

4.5.3 Need for Additional Responder Equipment and Tactics

During the Kalamazoo, Michigan, pipeline spill; after responders discovered the Dilbit had submerged to the sediment at the river's bottom, they developed a variety of tactics to collect the oil: spraying the

sediments with water, dragging chains through the sediments, agitating sediments by hand with a rake, and driving back and forth with a tracked vehicle to stir up the sediments and release oil trapped in the mud.

These tactics resulted in submerged oil working its way back up to the water surface, where it could then be collected using sorbent materials to mop up the oily sheen. While these tactics removed some oil from the environment, they may have also cause collateral damage; so the Natural Resource Damage Assessment trustees assessed impacts from the cleanup tactics as well.

For spilled oil that remains on the water surface for a period of days, response technologies exist, which could be deployed to contain, skim, transfer, and store highly viscous oil if environmental conditions at the spill site are amenable to the safe and effective operation of the equipment. The design of skimmers and pumps is predicated on the oil being available at, or quite near the water surface; and being recovered by the oil pickup mechanism of the skimmers (through adhesion), yet flowing at ambient temperature and/or when annular water flow is used in the pump.

If the spilled oil eventually assumes neutral buoyancy and becomes suspended between the water surface and the bottom, then it is unlikely that any response technologies can be successfully applied to significantly control the spill. Shoreline cleanup operations would have to be initiated; assuming oil strands and effective techniques can be identified and systematically applied to the affected shores.

If the spilled oil sinks to the bottom, then the literature points to the following possible response techniques and their inherent limitations:

- Methods of detecting sunken oil have advanced from sorbent arrays to the USCG's multi-beam sonar and fluorescence spectrometry systems. Sorbents have distinct shortcomings in both locating and retrieving submerged oil, while the systems' well-researched instrumentation remains limited in ability to define widely distributed oil. Underwater video recorders could assist in detecting oil if water clarity permitted. Sunken oil can continue to move and spread well after the initial release, further exacerbating its detection and monitoring.
- Strategies to contain sunken oil have not progressed beyond the conceptual stage. It can be expected that some sunken oil will collect in bottom depressions, yet still might move. Technologies that have proven effective have been only in low-flow zones or depressions (Counterspil Research, 2011).
- Based on U.S. Coast Guard research, multi-beam and imaging sonars are the most effective technologies for conducting wide area detection surveys and looking for large pools of subsurface oil. They are most effective in detecting subsurface pools if they are deployed before the oil breaks up. However, the resolution of these devices is still relatively low, impairing their effectiveness. Laser systems and narrower beam sonars are better suited to narrow areas and determining the amount of oil present (Hansen et al., 2009).
- Once sunken oil is located, the primary method applied in recovering the oil will likely be dredging operations using hydraulic submersibles with open impeller chambers operated by divers. Very minor amounts of oil versus the volume released have been collected with submersible pumps during actual spills. There are inherent dangers to divers when working at significant depths for prolonged periods. Submersibles and remotely-operated vehicles (ROVs) can be useful to both detect and collect sunken oil but are not known to be widely or quickly available. Successful use of recovery systems will still depend on the ability to locate sunken oil and the availability of oil accumulations in amounts that warrant their removal.

The final report of testing conducted at the National Oil Spill Response Research and Renewable Energy Test Facility (Ohmsett) in November 2011 and issued on January 23, 2012, noted the following with respect to the Oil Stop Bottom Oil Recovery System (OSBORS), provided by the Oil Stop Division of AMPOL:

> *"In excavator mode, limitations of the system, as tested, included its reach and depth of water that the system could be used in. There are "long stick" excavators that will allow for operation in up to 50 feet water depth. There is no reason to doubt the system will perform as demonstrated in deeper water. The footprint of the components can be operated from a standard deck barge or similar sized floating platform. Use of the EDDY pump with the remote controlled underwater Sub Dredge will resolve most of the reach and depth questions. The Sub Dredge can operate and pump oil from 200 feet depths and can range up to 350 feet away from the umbilical terminal. The testing at Ohmsett proved very valuable in the development of the OSBORS. Some areas exceeded expectations. Some aspects answered uncertainties. Shortcomings were noted, but not too alarming. The USCG-RDC had set a list of design concepts to be addressed in the testing. Of the nineteen items on the list, fifteen were able to be addressed, to some degree, during the Ohmsett testing. It could be justified that some of the items had more critical value than others in the overall evaluation. If one were to place the most gravity on the system's ability to remove sunken oil from the environment, first and foremost, then the consensus would be the test was a success. In the end,* ***<u>the tests provided confidence that the OSBORS is field ready and can be a very viable tool in recovering oil from the sea floor."</u>***

If oil is suspended in the water column, little can be done other than detecting the oil (Counterspil Research, 2011). During the DBL-152 heavy oil spill, hydraulic submersibles that featured open impeller chambers, such as the MPC model KMA axial/centrifugal pump, and directed by divers, proved to be most successful in removing sunken oil (Counterspil Research, 2011). The U.S. Coast Guard's research suggests that a hopper dredge or large duck-bill system has the highest potential for use in recovery efforts based on timing, operational limits, recovery efficiency, remobilization, cost, and safety (Michel, 2006). The Coast Guard Research and Development Center is partnering with the Bureau of Safety and Environmental Enforcement to develop new spill response technologies that detect and mitigate oil within the water column down to 10,000 feet. This effort is being pursued as a project titled, "Detection and Mitigation of Oil within the Water Column".

Transfer pumps should not be a limiting factor when dealing with viscous, submerged oils. Annular water injection, which forms a lubricating sleeve and greatly decreases resistance to flow, has dramatically improved the performance of commercially available Archimedes screw pumps. Available dredger pumps are also capable of moving oil once they contact it.

Table 8 and Table 9 list strategies for responses to oil spills.

Table 8. Technology and tactic options for nearshore and offshore geographic areas.

Technology/Tactic	Nearshore & Onshore	Offshore Includes Great Lakes
Surface Containment Strategies	X	
Berming	X	
Trenching	X	
Underflow/Overflow dams	X	
Sorbent barriers	X	
Containment booms on Surface	X	X
Water Jets	X	
Submerged Oil Containment Strategies (See Table 8)		
Bubble/Pneumatic Curtains	X	
Silt Curtains	X	
Surface-to-Bottom Nets/Screens	X	
Use of natural collection sites, e.g., pools above dam structures where the flow velocity decreases and submerged oil may settle and collect on the bottom.	X	
Detection-Tracking-Mapping Strategies (See Figure 14)		
Multi-beam/Imaging Sonar/side-scan sonar (NORBIT Sonar)	X	X
Divers w/Cameras	X	X
ROVs w/Camera	X	X
Aircraft (Visual Observation/Laser Sensor)	X	
Photobathymetry	X	X
Dragnets/Trawls		X
Chain drags/V-SORs	X	
Snare/Sorbent Drops/Stationary Sorbent Systems	X	
Grab Samples		X
Fluorometers (Laser, Towed, C-3)		X
Spectrometers-Infrared (FTIR) & Fluorescence		X
Integrated Video Mapping Systems	X	X
GPS tracking and plotting of removal operational activities	X	X
Recovery Strategies (See Figure 16)		
Net Environmental Benefit Analysis (NEBA) to determine removal activities and possible no removal action	X	X
SCAT Surveys (Shorelines)	X	
Diver directed or remote operated vehicle oil recovery operations/vacuuming and pumping (Ninja Oil Stop Bottom Oil Recovery System/integrated manned submersible system)	X	X
Dredging/Vacuum Systems	X	X
Surface Skimming Systems	X	X
Bottom Nets and Trawls; Sorbents/"Snare Monsters"	X	X
Bioremediation	X	
Chemical Cleaning Agents (Shoreline/Structures)	X	
Surface Dispersants (Excluding Great Lakes)		X
Agitation (wet tilling) using chains suspended from a towed bar to disturb the bottom sediment then remove oil on surface	X	

Table 8. Technology and tactic options for nearshore and offshore geographic areas (Continued).

Technology/Tactic	Nearshore & Onshore	Offshore Includes Great Lakes
Agitation (wet tilling) using low-pressure water flushing of shallow water bottom sediment then remove oil on surface	X	
Manual pickup of floating tar balls and shoreline cleaning	X	
Mechanical removal of contaminated soils w/heavy equipment	X	
Shoreline low and high pressure flushing w/ ambient or hot water then removed by sorbents/skimming	X	
Shoreline solid substrates or man-made structure steam cleaning	X	
Manual removal of submerged oil by divers	X	X
Capping Contamination	X	

Note: Most of the strategies shown in Table 8 can be utilized in fresh and salt water as well as in the nearshore and offshore environments. Some are limited to water depth for best optimized use, e.g. divers with appropriate level of diving gear, etc.

Table 9. Containment strategies.

Oil Is	Depth Is	Containment
Near Neutral Buoyancy (Oils Suspended in Water Column)	0-2 Meters (6.6') + or -	Physical Barrier
	0-3 Meters (9.8') + or - Maximum	Silt Curtain / Geofabrics Sorbent fences/barriers
	Working Depth Not Established	Pneumatic Curtain Contain Onshore
Negative Buoyancy (Oils Sinks to the Bottom)	0-2 Meters (6.6') + or -	Physical Barrier, e.g., gabion baskets)
	No Depth Restriction	Allow to collect in natural or artificial depression Contain Onshore

Source: Province of BC IR No. 2.46d-Attachment 1

Regional and national capacity to respond to an OSP spill is unclear, as most equipment lists do not provide information about applicability to different oil types. The USCG and EPA response equipment requirements for Group V oils that may submerge are extremely generic and lack any specificity as to equipment capability, capacity, and effectiveness. The regional and national equipment lists are missing key information about available oil spill response equipment capabilities, which makes it difficult to assess how a particular piece of equipment can be used effectively during a spill response scenario. There is additional equipment available as provided by companies to meet the requirements of the newest Salvage and Fire-Fighting Regulations that may address some of the concerns.

There is a lack of real world testing and experience with equipment suitable for OSP spills, which hinders the ability to assess whether or not a region has equipment that will be effective in an OSP recovery effort. Controlled experiments at meso-scale test facilities, such as the U.S. Department of Interior's National Oil Spill Response Research and Renewable Energy Test Facility in New Jersey, evaluating current equipment effectiveness on OSPs should be considered. A range of OSPs should be used to test the equipment, including different product types (Dilbit, Synbit, synthetic crude, etc.) and different bitumen sources (Cold Lake, McKay River Heavy, etc.), as well as different ambient conditions (e.g., salinity, temperature, and sediment load).

There is a continuing need to evaluate technologies and techniques for physical and chemical mechanisms that serve to detect, contain, remove, destroy or mitigate submerged oils/Dilbit when spilled into the environment. This need includes dispersant testing of fresh and weathered Dilbit and the continued evaluation of shoreline treating agents to assist in removing shoreline and vegetation contamination. Protocols should be developed for the use of chemical treating agents.

Recommendation:

For equipment for nearshore or offshore responses, the resource needs are known. The issue is not what "additional" equipment is needed; the primary issue is the absence of specific USCG regulatory requirements for the onshore/nearshore or offshore geographic areas for **any** specific type, specific quantity or specified arrival time frames for any equipment. When considering recommendations for "additional" equipment for nearshore or offshore, first one needs to ask where to find the existing specific requirements for any response resource in type, quantity, effectiveness, and availability to arrive within a certain time frame to a specific spill location. That is the deficiency and that is the primary issue that needs to be resolved before one can recommend any "additional" resources.

4.6 Lacking Toxicity Information

The NOAA technical memorandum points out that there are information gaps for environmental impacts from a Dilbit spill incident. Toxicity information specific to OSPs is scarce. Although results for discrete petroleum components—such as heavy oils or bitumens, natural gas condensates, or synthetic crude oils—exist, the toxicological and environmental effects of the many different permutations of OSPs are relatively unknown.

One of the most important determinants of environmental effects will be the behavior of the spilled OSPs in the environment; that is, will they float, sink, or become neutrally buoyant in receiving waters. As previously noted, this is extremely difficult to predict, given the range of oil mixtures and the range of environmental conditions that may be potentially encountered. This inability to predict the fate is not a technical difficulty. It results merely from the fact that there have been insufficient academic-level, research-level studies on the fate and transport mechanisms. Once studies have been completed for a variety of mixtures, the likely outcome for any specific mixture may be determined with suitable confidence. Research into fate and transport of a variety of oil/Dilbit systems is, therefore, urgently required.

Recommendation:

The Coast Guard should assist NOAA and other Canadian agencies, as needed, to determine the short-term and long-term environmental impacts of spilled bitumen blends in a variety of environmental and geographic conditions.

4.7 Risks of Increased Waterborne and Rail Transport of OSPs

The risks associated with increased waterborne and rail transport of OSPs are not well-defined. There appears to be a lack of research that would examine risks related to potential increases in tank vessel traffic, pipeline volumes, or rail traffic in or near the East Coast and Gulf of Mexico waterways, alongside or crossing major rivers—e.g., Columbia River in Washington State, Hudson River, and the Great Lakes. Consideration should be given to performing risk assessments that include the increased traffic in East Coast

and Gulf of Mexico waterways, major river crossings, the Great Lakes, and other waterways that could experience increased transportation of OSPs. Each risk assessment should identify or isolate the additional risk contribution represented by regional increases in OSPs transport. This assessment would be similar to a Waterway Suitability Assessment (WSA), which is currently required for waterways that see a new source or increase in volume of LNG and LHG transportation.

For that matter, current regulations do not require risk assessments related to oil sands bulk storage or marine transportation-related terminals until construction is already underway versus the USCG letter of notification or letter of intent procedure required for LNG/LHG facilities.

Recommendation:

More risk assessments of facility locations or marine transportation routes for blended bitumen; or of the risk and what may occur if a spill incident occurs at the facility or on the waterway should be performed. The U.S. Coast Guard has implemented specific Waterway Suitability Assessment processes to review and approve facilities and waterways that handle or transport LNG/LHG products, which, of course, have a risk of fire and explosion but minimal environmental impact; whereas blended bitumen, other than an initial early stage flammability possibility, carries a higher potential environmental impact. Consideration of a similar methodology might be prudent to review the impact on marine transportation safety on a waterway with the introduction of OSP transportation and handling to ensure that a risk evaluation is completed.

4.8 National Preparedness for Response Exercise Program (NPREP) Guidelines

The National Preparedness for Response Exercise Program (NPREP) Guidelines, currently undergoing revision (draft dated March 2015), does not adequately address the potential for Dilbit to submerge. Thus, revising the exercise guidelines to ensure that via exercises, the Responsible Party is prepared to respond to a Dilbit spill that may result in a portion of the material submerging beneath the surface (USCG, 2015). The Government Initiated Unannounced Exercises (GIUE) does not appear to emphasize that the Responsible Party and their contractors be trained and equipped to effectively respond to an OSP floating oil spill in which a significant proportion of the material may submerge beneath the surface.

With the current volumes and the forecast of continuing significant expansion of transportation, storage, and refining of bitumen/blended bitumen in the United States; it would seem that the NPREP Guidelines should significantly enhance its expectations for those Responsible Parties and transportation modes/nodes that are involved in the shipment and storage of this OSP. Therefore, one major disagreement with the proposed definition is the wording, "*are highly encouraged.*" This wording should be changed to requiring the conduct of appropriate submerged oil exercises at least once in the triennial cycle or, if the Responsible Party has significant movements of bitumen blends, requiring annual exercises concerning oils that may exhibit Group V qualities.

Recommendation:

The Coast Guard should consider adding a paragraph in the draft PREP Guidelines stating, *"For those Responsible Parties that transport, provide bulk storage, and refine Group V Oils <u>or oils that may exhibit similar qualities, when discharged into the environment,</u> Government Initiated Unannounced Exercises, IMT Exercises, Equipment Deployment Exercises and the evaluation of OSROs in exercises should include requirements, as appropriate, to include spills of Group V <u>or oils that may exhibit similar qualities when discharged into the environment."</u>*

5 PROPOSED RESEARCH TASKS

To summarize, this project reveals the need for new technologies for detecting, tracking, modeling, containing, protecting, recovering, decanting, and assessing oil spills, especially Dilbit spills. In general, the RDC is equipped to research and develop technologies related to detecting, tracking, containing, recovering, and decanting oil spills. These technologies however, need to be emergency ready, pre-packaged, with trained and available operator personnel. This project has also revealed the need for more guidance and information for the FOSC responding to an oil spill; as well as a need for improved decision making tools for responders. The RDC is also positioned to assist in developing FOSC guidance for these types of oil spills.

5.1 Technology Issues

5.1.1 Modeling and Prediction

There is a need to improve our understanding of the chemistry of submerged oil and better predict the fate of the oil and its transport/trajectory through the water column or along the bottom. Potential modeling resources should be developed to predict submerged oil transport/trajectories on short and long term time scales. Models for near term tactical response applications may in all likelihood differ from longer term damage assessment applications. Development of modeling software that provides responders with time sensitive potential spill trajectories or movement of submerged oil for tracking and recovery during a response would be the objective. This potential modeling resource would improve the ability of a FOSC and the Response Management Organization to conclude a successful response. The development of a Submerged Oil Trajectory Modeling Tool for use by responders and the FOSC would assist decision making on the optimal use of response resources when the response entails submerged oil. Environment Canada is pursuing research in this area; but lack of real world data for behavior is inhibiting this research.

5.1.2 Containment

There is an obvious need to improve upon current submerged oil barriers. There is a continuing need to evaluate and test different approaches to contain, divert, collect, and improve recovery of oil on the seafloor. These containment barriers could include bottom boom, fences, bales, nets, etc. The evaluation of containment systems need to consider typical characteristics of submerged oil. Barriers should function effectively in a range of bottom current conditions, be flexible, possess the ability to be rapidly deployed and be appropriately adjustable to meet the dimensional requirements of the deployment site. Procedures and capabilities should be in place to enable the responders to track the barrier's location and the efficiency of the barrier. Tracking the location and efficiency may involve other technologies, e.g., sonar to track the barrier's location and multi-beam sonar and fluorescence spectrometry systems stationed downstream to detect submerged oil bypassing or escaping the barrier. The results of RDC project 4702, Detection and Mitigation of Oil in the Water Column may contribute to this area; but more work is needed for coastal and inland areas.

5.1.3 Recovery

Improvement of current submerged oil recovery systems for oil on the seafloor is needed. In particular, dredges should be modified to minimize water and sediment uptake. Dependence on divers could be reduced by developing automated/unmanned systems, improving product recovery rates, and expanding operational capabilities/parameters. A 2013 USCG RDC project provided the recommendation that

additional research be conducted in the following areas which may be applicable to Dilbit under some conditions (USCG RDC, 2013):

- Lab tests to determine range of oil that can be pumped for the various types of pumps and nozzle arrangements, including maximum water depth and hose length at which the pumping system is able to function.
- Cost/benefit analysis of the different types of pumps and delivery systems based on the location of the spill, including depth, bottom type, available logistical support, and environmental impact.
- Performance of pumping systems if using water injection, especially when oil flow is intermittent.
- The operational limits and optimal depths need to be determined for the various recovery delivery systems.
- Continued improvement in the ability to maximize oil removal and minimization of water intake.

5.1.4 Decanting

During the Ohmsett tests in November 2011, it was found that the oil and water decanting and free oil removal from the storage tanks were not a total success; but enough knowledge was attained to demonstrate the viability of the system as it was designed for the tests. The main issue observed was that, due to the high volume of materials recovered by the pump, a more fluid and continuous decanting operation needs to be developed to allow for uninterrupted recovery pumping (USCG RDC, 2012).

Improvement in oil separation/decanting systems is needed; since decanting arrangements appear to usually be ad hoc, under designed, had a tendency to fail, and needed numerous trials and errors. There is a need for guidelines and calculation tools, consideration of droplet size, flow rates, oil behavior (will it float or not), and still be able to use readily available materials. A USCG RDC project concluded that responders need to develop detailed guidance and/or computational tools for decanting systems, based on the conditions of the spill (USCG RDC, 2013). Such tools would explicitly take into account oil and sediment characteristics, as well as the volume flow rates desired for the recovery process, especially for fresh water.

A possible area for further study is to determine whether the topography and sediment characteristics, along with those of the oil involved, can be characterized to permit optimizing a decanting system for a particular situation. This needs to done at the beginning of the spill response, rather than by modifying and adapting the system in situ, in response to observations that are made during the decanting system's operation.

5.1.5 Detection and Sampling

The US Coast Guard is currently evaluating airborne remote sensing capabilities for oil spills on their aircraft platforms. Airborne remote sensing technologies, such as LIDAR, have not been used at any spill of submerged oil; because little is known about their potential effectiveness at detecting oil on the seafloor under different conditions of water depth, turbidity, bottom type, oil thickness and percent cover.

Also, little is known about the turn-around time from data acquisition to useful product for different types of sensors. Additional research into existing above-water remote sensing technologies to determine which systems have the best potential for use for submerged oil detection is needed.

A 2014 USCG RDC project was conducted to identify, further develop, and test systems that can detect and characterize oil that is entrained and dispersed in the water column (USCG RDC, 2014). Two prototype systems demonstrated the qualitative ability to detect and/or map oil suspended in the water column. The wide band Multibeam sonar and the wide-angle-scattering inversion system prototypes showed promise in

their abilities to quickly determine the presence of oil and relay the information to responders. In turn, responders can make timely decisions to mitigate the impact of the submerged oil on the surrounding environment and infrastructure. Both systems need further testing, evaluation, and development to become practical tools. Generally, the detection and monitoring tests that were conducted showed:

- There is no single method that can cover 100 percent of the area with no false alarms;
- Resolution is still an issue: easier if oil stays together, random hits must be correlated;
- Turbid water and very soft bottom (such as in rivers and harbors) are also issues;
- Additional research is needed for real-time mass spectrometry systems;
- Use of multiple sensor types should reduce false detections;
- And sampling fluorescence and sonar both typically rely on a point sampling system configured either in a towed or in a robotic configuration, adding both expense and complexity.

In short, there are very few truly effective alternatives for sampling the water column over a large area to determine the extent of intrusion of an oil spill into the water column.

5.1.6 Chemical Countermeasures

There is a need to identify, evaluate, and develop chemical countermeasures that are effective in dispersing, encapsulating, or containing submerged oil. Specific examples of assessments/evaluations that are needed include:

- Use of surface application of dispersants on Dilbit in the initial stages of a spill while it is still floating and within a determined window of opportunity;
- And use of chemical cleaning agents for Dilbit spills that have contaminated shoreline and structures.

In addition to evaluating chemical countermeasures, associated policies need to be developed to govern their proper use particularly for chemical cleaning agents that would be used for shoreline remediation or cleaning of structures contaminated by the oil. Some initial work was done for short-term spills in salt water (see GFI 4 in Section 6) but more needs to be done for fresh water.

5.2 Information Development

5.2.1 Information Development: Water Intake Systems

There is a need for improved technologies and engineering guidelines for deployment of systems that will protect water intakes located in streams, rivers, lakes, or underground aquifers during spills where oil becomes suspended in the water column. Specific examples include:

- Develop threshold guidelines (matrix by industry/use) for shut down/restart of water treatment systems;
- Identify protection methods and treatment systems;
- Educate/train water treatment system operators and oil spill responders;
- And provide information to facilitate communications during planning and response.

There is also a need for improved design of filter fences, curtains, or air bubble curtains to prevent the spread of oil suspended during recovery operations into water intakes. This could be a complex project because of the range of conditions; however, designs and guidelines could be developed for a few typical conditions which would assist in developing local contingency planning.

5.2.2 Information Development: Submerged Oil Guidance

The RDC final project report in June 2013 provided guidelines in Part B for FOSCs responding to spills of sunken oil (USCG RDC, 2013). The intent of the guidance was for the user to lift this text out of the RDC report and insert it into an appropriate FOSC guidance documentation, e.g., ACPs/GRPs, etc., so that it would be readily available during a response. Given the elevated risk of a Dilbit spill that could become a sunken oil spill, there is a need to insert the submerged oil response guidance available in this RDC Report into ACP's/GRPs.

5.2.3 Information Development: API Publication Revision

The 1995 version of the American Petroleum Institute (API) Publication #4558-1995*, Options for Minimizing Environmental Impacts of Freshwater Spill Response,* is currently being revised (American Petroleum Institute, 1995). There is a need to include a complete section on submerged oils in the revised version to permit industry be better prepared in responding to submerged oils.

5.2.4 Information Development: Decision Making

Development of effective rapid-assessment protocols are needed to determine impacts of submerged oil spills. These protocols should describe general methods for collecting source oil, water, sediment, and biological samples during a response to a submerged oil spill. Sample data would be useful for both response decision making; and to assist with the cooperative Natural Resource Damage Assessment that may be implemented in the event of a submerged oil spill.

5.2.5 Information Development: Dilbit Behavior

The following additional information regarding Dilbit behavior is needed:

- Dilbit's mixture of heavy and light components makes it highly susceptible to weathering-induced changes, which causes it to be more difficult to predict whether and when it will become submerged or sink. This requires more samples in more media to track the fate of the oil, compared to other oils that better fit existing predictive models. Overall, Dilbit behavior does not fit well into existing paradigms for oil, and thus basic data are needed to guide future work. Development of a decision template or conceptual model of the conditions under which oil might become submerged, that includes oil properties and environmental characteristics, would provide better guidance to predict how much of the spilled oil will be a subsurface issue. This guidance would apply initially and over time after weathering, sediment interactions, etc. has occurred.
- There is little information available on how sediment agitation and similar tactics affect the environment; and how those impacts compare to the toxicity of the oil. More toxicity studies and further assessment of the effects of cleanup-related physical disturbances are needed to appropriately balance the cleanup with natural recovery.
- Various bitumen blends may act differently in the environment and may pose differing environmental, safety and health issues to responders and the public; underscoring the need for additional research of each bitumen blend. Each bitumen blend should have a MSDS for the specific characteristics of that blend; showing the percentage of the diluent, the chemical components of the diluent, flammability, hazard, and health information specific for that blend.

6 GFI SOURCES

The following documents were listed in Section 1.3.2 of the USCG Research and Development Center's (RDC's) Statement of Work for this study.

1) Federal Government Technical Report, Properties, Composition and Marine Spill Behaviour, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands. Environment Canada Emergencies Science and Technology; Fisheries and Oceans Canada Centre for Offshore Oil, Gas and Energy Research; Natural Resources Canada. (November 30, 2013) (http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=D6AB8B67-73F5-48B6-B3D1-AAE1B06FF9A2)
2) NOAA Report: What Are the Increased Risks From Transporting Tar Sands Oil? http://response.restoration.noaa.gov/about/media/what-are-increased-risks-transporting-tar-sands-oil.html
3) A Review of Countermeasures Technologies for Viscous Oils that Submerge. http://www.acee-ceaa.gc.ca/050/documents_staticpost/cearref_21799/83874/A_Review_of_Countermeasure_Technologies.pdf
4) Study of Fate and Behavior of Diluted Bitumen Oils on Marine Waters. http://www.transmountain.com/uploads/papers/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf
5) Emerging Risks Task Force Report - 2013. http://www.millenniumbulkeiswa.gov/comments/MBTL-EIS-0002439-58970.pdf
6) Canadian Energy Pipelines Association State of the Art Report Dilbit Corrosivity Document Number: 12671-RPT-001 REV 1.[1] http://www.cepa.com/wp-content/uploads/2013/02/FINAL-Penspen-Report-Dilbit_Corrosivity_Final.pdf
7) University of New Hampshire, CRRC Oil Sands Workshops. http://crrc.unh.edu/workshop/cse/oil-sands-products-forum-working-group http://crrc.unh.edu/workshop/cse/alberta-oil-sands-training
8) National Wildlife Federation. http://www.nwf.org/News-and-Magazines/Media-Center/Reports/Archive/2012/10-18-12-Sunken-Hazard.aspx
9) Tar Sands Pipelines Safety Risks. http://www.nrdc.org/energy/files/tarsandssafetyrisks.pdf
10) A Comparison of the Properties of Diluted Bitumen Crudes with other Oils and other Transmountain Reports. http://www.transmountain.com/diluted-bitumen-info
11) *Great Lakes Disasters, Utilizing Earth Observations to Plan for Diluted Bitumen Submergence, Technical Report Final Draft.* (July 24, 2014).
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Merna Saad, Christopher Newport University; Frederick Aulwes, U.S. Air Force;
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[1] The URL for this ITEM reflects a correction to the URL given for this document.

12) Merv Fingas, Spill Science. Edmonton, Alberta, Canada. *Review of Diluted Bitumen Properties Relevant to Spill Cleanup.* Group V Oil Forum, Detroit, MI. (September 9-10, 2014).

13) National Academy of Science. (2013) TRB Special Report 311: Effects of Diluted Bitumen on Crude Oil Transmission Pipelines
https://www8.nationalacademies.org/cp/projectview.aspx?key=49461
http://nas-sites.org/dilbit/

14) *A Study of the Safe Transport of Hydrocarbons by Pipelines, Tankers and Railcars in Canada*.
http://www.parl.gc.ca/Content/SEN/Committee/411/enev/rep/rep12aug13-e.pdf

15) Etkin, Dagmar Schmidt. Risk of Crude and Bitumen Pipeline Spills in the United States: Analysis of Historical Data and Case Studies (1968-2012). *Proceedings of the Thirty-Seventh AMOP Technical Seminar on Environmental Contamination and Response*. Canmoe, Alberta, Canada. June 3-5 2014.

16) National Energy Board. *Estimated Canadian Crude Oil Exports by Type and Destination.*
https://www.neb-one.gc.ca/nrg/sttstc/crdlndptrlmprdct/stt/stmtdcndncrdlxprttpdstn-eng.html

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APPENDIX A. BITUMEN EXTRACTION, DILUENTS AND DILBIT PROPERTIES

In pursuing heavy oil and bitumen resources, the energy industry historically focused on sand deposits. These deposits were first encountered by aboriginals thousands of years ago as riverbank outcrops with naturally seeping bitumen, which they and early European explorers used to seal their canoes. Beginning in the 1960s, the oil sands were developed through a combination of surface mining and underground or *in situ* development. Tar sands deposits are found in over 70 countries; but most of the world's reserves are in two regions: Alberta (Canada) and Venezuela. Between them, the Canadian and Venezuelan deposits contain an estimated 3.6 trillion barrels of oil (Chopra, Lines, Schmitt, & Batzle, 2010).

A.1 Bitumen In Situ

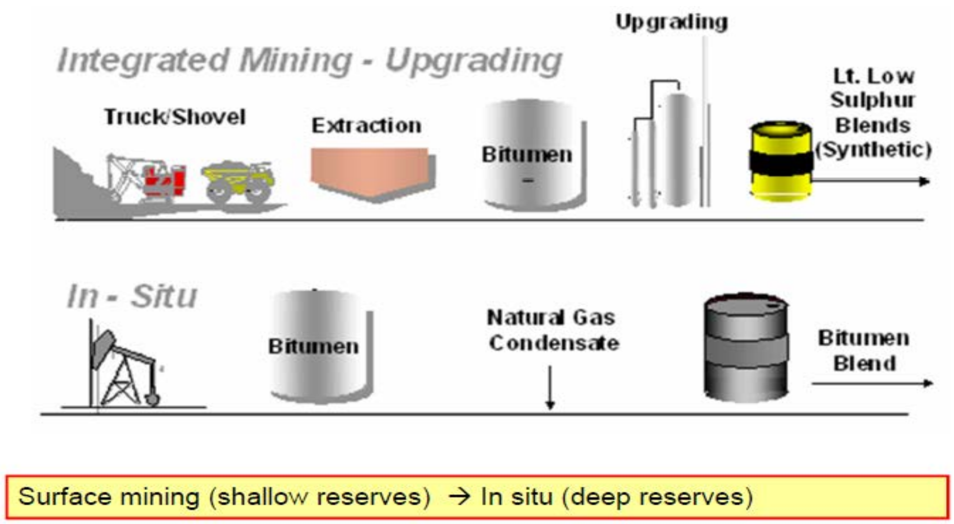
Bitumen in situ is contained in a mix of sand, clay, and water. It is separated from the sand, clay, and water in a centrifuge prior to dilution for transportation. At room temperature, it is much like cold molasses. The World Energy Council (WEC) defines natural bitumen as "*oil having a viscosity greater than 10,000 centipoise under reservoir conditions and an API gravity of less than 10° API*." In order to transport bitumen in situ through pipelines, a diluent is added to the bitumen. The combination of bitumen with diluent produces a homogeneous blend, Dilbit, which has considerably lower density and viscosity with good pumping and flow properties. The diluent used could be lighter crude oils, synthetic crude oils, or natural gas condensates.

A.2 Open Pit Mining

According to the Government of Alberta: "As of July 2013, there were 114 active oil sands projects in Alberta." Of these, six were producing mining projects (three more are under application); the remaining projects use various in situ (in place) recovery methods."[2] According to Oil Sands Today (www.oilsandstoday.ca), a website of Canada's Oil Sands Producers, approximately 20 percent of the oil sands lie close enough to the earth's surface to be mined, which impacts three percent of the surface area of the oil sands region. Open-pit mining is similar to many coal-mining operations. Large shovels scoop the oil sands into trucks, which take it to crushers, where the large clumps of clay are broken down. The oil sands is then mixed with water and transported by pipeline to a plant, where the bitumen is separated from the other components. Tailings ponds are an operating facility common to all types of surface mining. For oil sands, tailings consisting of water, sand, clay, and residual oil, are pumped to these basins—or ponds—where settling occurs and water is recycled for reuse in the process. When the ponds are no longer required, the land will be reclaimed (Canada's Oil Sands Producers, n.d.).

A.2.1 In Situ Drilling

The majority of the oil sands lie more than 200 feet below the ground and are too deep to be mined. These reserves can be recovered in situ by drilling wells. In situ drilling accounts for 80 percent of oil sands reserves; these reserves are located below 97 percent of the land in the oil sands sector. Figure A-1 below depicts the current oil sands business.

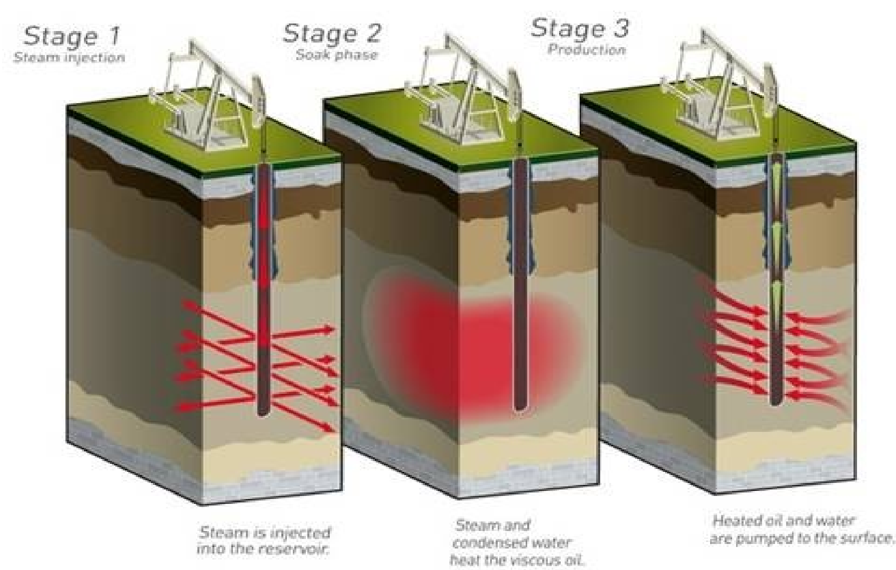


Source: (Upgrading & Refining presentation)
Government of Alberta web site, Alberta's Oil Sands, extracted from http://oilsands.alberta.ca/resource.html

Figure A-1. Current oil sands business.

A.2.1.1 Cyclic Steam Stimulation (CSS) Process

In situ development initially utilized vertical wells in a Cyclic Steam Stimulation (CSS) process. As shown in the following figure from the Total website (Total S.A., 2015), Cyclic Steam Stimulation is used to extract viscous heavy oil. Steam is pumped at high pressures underground to reduce the viscosity of the oil. When the steam and condensed water heat the oil, the flow rate increases and viscosity decreases, making it easier to pump the viscous heavy oil up to the surface.

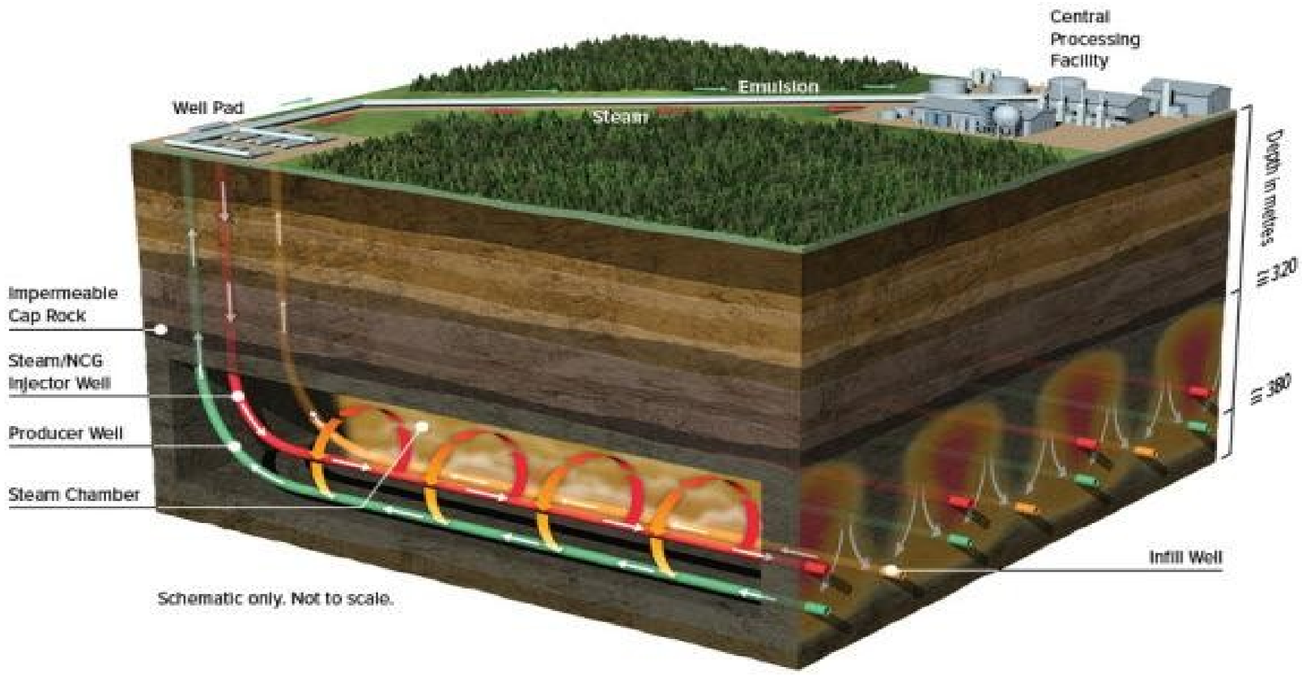


Source: (Total S.A., 2015)

Figure A-2. Diagram of cyclic steam stimulation process.

A.2.1.2 Steam Assisted Gravity Drainage (SAGD) Process

More recently, horizontal wells produce oil with the Steam Assisted Gravity Drainage (SAGD) process. As shown in the following figure, SAGD is an enhanced oil recovery technology for producing heavy crude oil and bitumen. It is an advanced form of steam stimulation, where pairs of stacked horizontal wells are drilled into the reservoir approximately 400 meters beneath the surface. The top well injects steam to heat the bitumen, which separates from the sand and collects with the produced water in the lower well, approximately five meters below. The bitumen is then pumped to the surface, where it is separated from the water. The water is treated and recycled into the system.



Source: Meg Energy website (Meg Energy, n.d.)

Figure A-3. Diagram of Steam Assisted Gravity Drainage (SAGD) process.

A.3 Carbonates

Geologically, in addition to oil sands, another geological formation is available: the carbonates. Carbonates are sedimentary rock, such as limestone, formed from decayed organisms such as coral and plankton. In fact, approximately 59 percent of Alberta's conventional crude oil is hosted within carbonate rocks. Since the first oil discovery at the Leduc No. 1 in 1947, Alberta discovered and successfully produced over 9.8 billion barrels of crude oil from carbonate rock. Alberta's combined bitumen resource base includes an estimated 471 billion barrels in the Grosmont and Winterburn carbonates, all of which remains undeveloped.

In a July 2014 Oil & Gas Journal article, Mike Priaro discusses Alberta's bitumen carbonates (Priaro, 2014). Grosmont carbonate contains bitumen with properties similar to the bitumen sands but in reservoir rock with rock properties different from the unconsolidated bitumen sands. Unconsolidated sandstones are sandstones, or sands, that possess no true tensile strength arising from grain-to-grain mineral cementation. These rocks are friable, which means an intact sample can be easily broken apart by hand into individual grains. The

Grosmont carbonate formation is believed to contain approximately 243 billion barrels of recoverable reserves, equivalent to approximately 28 percent of the recoverable Alberta bitumen oil deposits.

In a September 2014 article in Alberta Oil, Jesse Snyder compares the deposit of carbonate bitumen in Alberta, in terms of size, to the oil sands—a deeper, harder, heavier version of the Athabasca Formation. According to the article, if only one third of the carbonate resource were proven recoverable, Canada could become the top-ranking country in the world in terms of oil reserves, ahead of Saudi Arabia and Venezuela. But there is a catch. To date, no company has managed to commercially produce oil from the formation despite various attempts dating back to the 1970s. Carbonate bitumen is not included in provincial reserve estimates (Snyder, 2014).

A.4 Diluents

Natural-gas condensate is a low-density mixture of hydrocarbon liquids that are present as gaseous components in the raw natural gas produced from many natural gas fields. It condenses out of the raw gas if the temperature is reduced to below the hydrocarbon boiling point temperature of the raw gas mixture. Because condensate is typically liquid in ambient conditions and also has very low viscosity, condensate is often used to dilute highly viscous heavier oils that cannot otherwise be efficiently transported via pipelines. In particular, condensate is frequently mixed with bitumen from oil sands to create Dilbit.

There are many condensate sources worldwide; each has its own unique gas condensate composition. However, in general, gas condensate has a specific gravity ranging from 0.5 to 0.8, and is composed of hydrocarbons, such as propane, butane, pentane, and hexane. Natural gas compounds with more carbon atoms (e.g., pentane or blends of butane, pentane, and other hydrocarbons with higher molecular weight) exist as liquids at ambient temperatures. Additionally, condensate may contain additional impurities such as the following:

- Hydrogen sulfide (H_2S);
- Thiols traditionally also called mercaptans;
- Carbon dioxide (CO_2);
- Straight-chain alkanes;
- Cyclohexane and perhaps other naphthenes;
- And aromatics (benzene, toluene, xylenes, and ethyl benzene).

A series of articles by RBN Energy LLC describe the flow of diluents from the United States to the Alberta oil sands production fields and provides other important information concerning diluents (RBN Energy LLC). Demand for diluent, such as natural gasoline and condensate, is forecast to increase from 380 million bbl/d in 2014 to 685 million bbl/d by 2019. Increasing bitumen crude production in the Western Canadian oil sands region drives that demand. New large scale bitumen projects in Alberta require two pipelines—one to ship crude production to market and one to receive diluent for blending.

There are two diluents (blending agents) currently in use—Naptha and Synthetic Crude Oil (SCO). Condensate (naphtha), which is a very light hydrocarbon (approximately 65 API), is blended in a ratio of 70 percent bitumen to 30 percent condensate to create Dilbit. SCO, which is bitumen that has been processed by an upgrader, is blended in a ratio of 50:50 to create SynBit. The goal of this blending is to achieve a product that meets pipeline transport specifications which are contained in Section A5.

The costs associated with diluent acquisition and use can significantly raise the effective transportation cost for the producer. These diluent costs include: acquisition costs; pipeline transportation costs for the diluent from a central terminal to the production field; the cost of blending; the costs of moving the diluent in Dilbit from the field via a pipeline terminal; and the pipeline toll from the terminal to the refining center, less the value of the diluent at the end-use refinery. Increasing production of bitumen has strained and will continue to strain the limited supply of diluent, which will force producers to look for ways to access additional diluent supply or develop new methods of reducing viscosity without adding diluent.

The following figure shows the first and most significant pipeline system delivering diluent to Western Canada from the United States, which is the Enbridge Southern Lights that came online in July 2010. Southern Lights runs from Manhattan, IL to Enbridge's Terminal in Edmonton, Alberta. The pipeline consists of new construction from Manhattan to Clearbrook, IL and the reversal of Enbridge's Line 13 from Clearbrook to Edmonton, following the route of the Enbridge Mainline (Fielden, 2014).

Source: (Fielden, 2014)

Figure A-4. Enbridge southern lights pipeline system.

The combined capacity of the TransCanada Grand Rapids, Enbridge Norlite, and Devon/MEG Access pipelines, currently being planned and built, will allow delivery of an extra one million bbl/d of diluent to oil sands producers by 2017. That is more than producers currently expect to need until 2030. The diluent will be shipped north from Edmonton terminals to production plants and then blended with bitumen before making the return trip as Dilbit or Railbit destined for long-haul transport by pipe or rail to U.S. and Canadian markets. Railbit is defined as bitumen that has been mixed with approximately 15 percent diluent.

Transporting Railbit rather than Dilbit saves shippers approximately half of the "diluent penalty", or the cost of adding diluent to the bitumen. Railbit must be heated in special tank cars to be unloaded and tank cars transporting Railbit must be insulated.

A.5 General Dilbit Specifications

In a 2012 presentation to the National Academy of Science Committee, Heather Dettman provided some basic specifications of bitumen and diluent as follows: (Dettman, 2012)

Bitumen and diluent mixtures can be identified by different names:

- "Raw bitumen" contains no diluent and requires insulated tank cars with steam coils for transportation.
- "Railbit" contains ~15% diluent and is transported by insulated tank cars.
- "Dilbit" contains ~30% diluent and is transported by pipeline.

Dilbit must meet quality specifications that are posted with the National Energy Board (NEB) in Canada and the Federal Energy Regulatory Commission in the U.S. The specifications are as follows:

- Density @ 15°C/59°F $\leq$ 940 kg/m^3.
- Viscosity @ pipeline temperature $\leq$ 350 cSt.
- Basic sediment and water content (BS&W) $\leq$ 0.5 vol%.

Dilbit is the mixture of diluent and bitumen that meets pipeline specifications that meet federal laws for density and viscosity.

- Approximately 30vol% of diluent is used in the mixture.
- Consists of components that boil over the full range of both oils, from -0.5°C/31.9°F to over 750°C/1382°F.
- Characteristics of Dilbit include:
  - TAN* value in the range of 1.6mg KOH/g.
  - Sulfur content of 3.9wt%.

*Note: Total Acid Number (TAN) is the measure of acid concentration in a non-aqueous solution. It is determined by the amount of potassium hydroxide (KOH) base required to neutralize the acid in one gram of an oil sample. The standard unit of measure is mg KOH/g.

An example of diluent is CRW condensate.

- CRW is a naphtha-based oil, which can include natural gas condensate.
- Natural gas condensate is the liquid that is produced with natural gas where the lowest boiling component is butane, which boils at -0.5°C/31.9°F.
- Approximately 75wt% of the condensate boils at temperatures less than 204°C/399.2°F.
- Initial boiling point is 204°C/399.2°F.
- Final boiling point is approximately 524°C/975.2°F.
- Biodegradation has resulted in organic acids being left behind in the oil.
- Total acid number (TAN) is 3mg KOH/g which corresponds to an organic acid content of 3wt% in the oil.

Organic acid species in bitumen are relatively large molecules with 70wt% boiling above 524°C/975.2°F. Table A-1 provides an example of quality specifications for component streams to the CRW (Condensate Blend) Pool.

Table A-1. Quality specifications for component streams to the CRW pool.

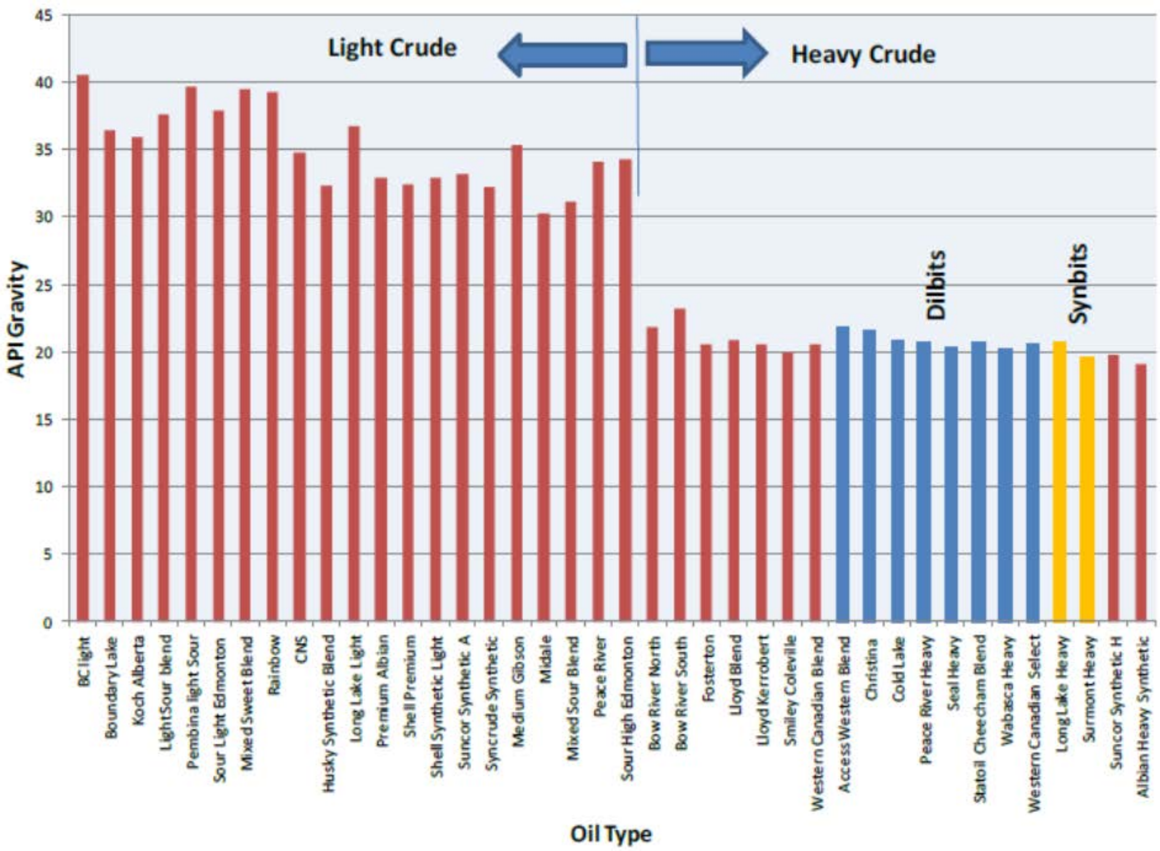
Property	Minimum	Maximum
Density	600 kg/m³ (104°API)	775 kg/m³ (51°API)
Kinematic Viscosity (7.5° C)		2.0 cST
Sulfur, total		0.5wt%
Reid Vapor Pressure		103 kPA (14.9 psi)
Benzene		1.6 vol%
Aromatics, total (BTEX)	2.0 vol%	

Source: (Lindley, 2013)

Due to the broad range of material that can be used as diluent, the Canadian market has defined an Equalization Practice which, in the simplest terms possible, financially compensates (or penalizes) each diluent shipper based upon the difference in the product quality delivered into and received from the pipeline (or blend pool).

A.6 Comparison with Other Crude oils

The 2013 CEPA study advises that crude is usually classified according to its API gravity and sulphur content. Dilbit and Synbit are classified as heavy sour crudes. The following figure compares their API gravity with some other conventional Canadian crude. Dilbit and Synbit have an API gravity of approximately 20, which is similar to other conventional heavy crude (Canadian Energy Pipelines Association, 2013). Figure A-5 shows the API gravity of Dilbit and Synbit in relation to other conventional crudes from Canada. Table A-2 shows comparison of physical properties for a broad range of oil types.



Source: (Canadian Energy Pipelines Association, 2013)

Figure A-5. API gravity of Dilbit and Synbit in relation to other Canadian conventional crudes.

Table A-2. Physical properties of crude oils.

Property	Units	Oil Types							
		Gasoline	Diesel	Light Crude	Dilbit1	Heavy Crude	Intermediate Fuel Oil	Bunker C	Crude Oil Emulsion
Density	Kg/m3 at 15oC	720	840	780 to 880	824 to 941	880 to 1000	940 to 990	960 to 1040	950 to 1000
API Gravity		65	35	30 to 50	18 to 39	10 to 30	10 to 20	5 to 15	10 to 15
Viscosity	mPas at 15oC	0.5	2	5 to 50	270.5* to 265,263 **	50 to 50,000	1,000 to 15,000	10,000 to 50,000	20,000 to 100,000
Flash point	15oC	-35	45	-30 to 30	<-35**m to 58*m	-30 to 60	80 to 100	>100	>80
Solubility in Water	ppm	200	40	10 to 50	-	5 to 30	10 to 30	1 to 5	-
Pour Point	oC	NR	-35 to - 1	-40 to 30	-30**m to 15**m	-40 to 30	-10 to 10	5 to 20	>50
Interfacial Tension	mN/m at 15oC	27	27	10 to 30	27*m to 150*m	15 to 30	25 to 30	25 to 35	-

Modified from (Fingas, 2001); [1]Values provided include weathered Dilbit from tests; NA= not relevant;
* Calculated for AWB; ** Calculated value for CL;*m Measured value of AWB; **m Measured value of CL

Source: (Polaris Applied Sciences, 2013)

Petroleum-based oils range from naturally occurring materials, such as condensate, crude oil, bitumen, and tar, to refined processed products, such as aviation fuels, gasoline, and lube oils (Polaris Applied Sciences, 2013). Whether naturally occurring or processed, petroleum-based oils encompass a wide range of physical and chemical properties.

A.6.1 Classification of Pool Types of Oil

The oil spill response community has developed different classifications to pool types of oil. Classifications include:

- Persistent and non-persistent (see examples used in Alaska Dept. of Environmental Conservation regulations, Oil Pollution Preparedness, Response and Cooperation (OPRC) Conventions, and International Tanker Owners Pollution Federation).
- Groups 1 through 5 (or I through V).

In the United States, the EPA and USCG define petroleum-based oil groups as shown in Table A-3. The data in the table shows Dilbit as a Group 3 oil.

Table A-3. Characteristics and examples of petroleum-based oil groups

Group	Density (g/cc)	API	Examples
Group 1	<0.8	>45.2	Gasoline, Kerosene
Group 2	0.8 – 0.85	45.2 – 34.8	Gas Oil, Alberta Light Crude
Group 3	0.85 – 0.95	34.8 – 17.3	Alberta Medium to Heavy Crude-Dilbits
Group 4	0.95 – 1.0	>=10 and <=17.3	Intermediate Fuel Oil (IFO), 180 (Bunker B), IFO>=380 (Bunker C)
Group 5	>1.0	<10	Orimulsion, Boscan Crude

Source: (Polaris Applied Sciences, 2013)

A.6.2 Oil Spill Response Regulatory Requirements

The above table is important to note. The oil spill response regulatory requirements by all Federal regulatory agencies for Dilbit would require the Responsible Party to have contracted response resources capable of responding to a Group 3 oil incident. Regulations do not require the Responsible Party to plan for or have response resources capable of responding to a Group 5 oil incident even though a portion of that Group 3 oil (e.g., Dilbit) may submerge beneath the surface of a waterway upon release into the environment just as other crudes behave. This aspect is also true for the regulatory agencies themselves in that there is no requirement for the USCG or EPA to include oil spill scenarios in the Area Contingency Plans (ACPs) or the ACPs' Geographic Response Plans (GRPs), for any Group 3 oil that may, under certain circumstances, have a portion of the spilled material submerge similar to a Group 5 oil.

A.6.3 Dilbit Flammability Classifications

Most fresh oils are initially considered flammable; however, medium, heavy, and Dilbit oils move into the non-flammable classification after a short weathering period. Dilbit is classed as a Flammable liquid by the Workplace Hazardous Materials Information System (WHMIS) criteria. WHMIS is Canada's national hazard communication standard WHMIS. Dilbit is also classed as a Flammable liquid by the U.S. Occupational Safety & Health Administration (OSHA) criteria. Released vapors may form

flammable/explosive mixtures. Vapors may travel considerable distances to ignition sources and cause a flash fire.

The Alberta Innovates-Technology Futures 2014 report provides flash point data for crude oil. The following table shows open cup flash point values for various crude types (Jokuty, 2005).

Table A-4. Open cup flash point values for various crude types.

Oil Type	Flashpoint (◦C)
Dilbit	-35
Conventional Light/Medium	7
Conventional Heavy Crudes	<12
Light Sweet Crude	-9.1
In-Situ Heavy Crude	151
Diluent	<-35

Source: (Jokuty, 2005)

According to the above table, the flash point of fresh Dilbit is lower than other crudes and comparable to the diluent. As mentioned in the Alberta Innovates-Technology Futures document, the flash point of a material is determined by the lowest boil point components (volatiles); therefore, the flash point of Dilbit is governed by the 20–30 percent volume of the diluent component and the flash point will increase as the diluent evaporates during weathering. Table A-5 shows the comparison of flashpoints before and after weathering (Jokuty, 2005).

Table A-5. Comparison of oil type flashpoints (ASTM D92) before and after weathering.

Oil Type	Flashpoint (◦C)		Mass Loss (%)
	Fresh	Weathered	
Dilbit	<35	88	16
Conventional Light/Medium	<35	96	15
Conventional Heavy Crudes	<35	142	19
Light Sweet Crude	<35	146	37
Diluent	<35	128	81

Source: (Jokuty, 2005)

Oil exposed to the atmosphere after an initial release will undergo a natural weathering process that is determined by the local environment. The results of the testing shown in the above table were collected for the crude oil samples after they underwent 48 hours of weathering. As the data shows, flash point levels rose significantly after weathering, due to the evaporation of the lighter ends within all the oils with all flash points being above 37.8°C. The Dilbit was found to behave similarly to conventional heavy crude oil after weathering, with similar flash points and weight losses. Importantly, the data seems to reveal that weathered Dilbit has a flash point of 88°C/190°F, suggesting that the flammability and explosion potential would be reduced as Dilbit undergoes weathering after being released into the environment (Jokuty, 2005).

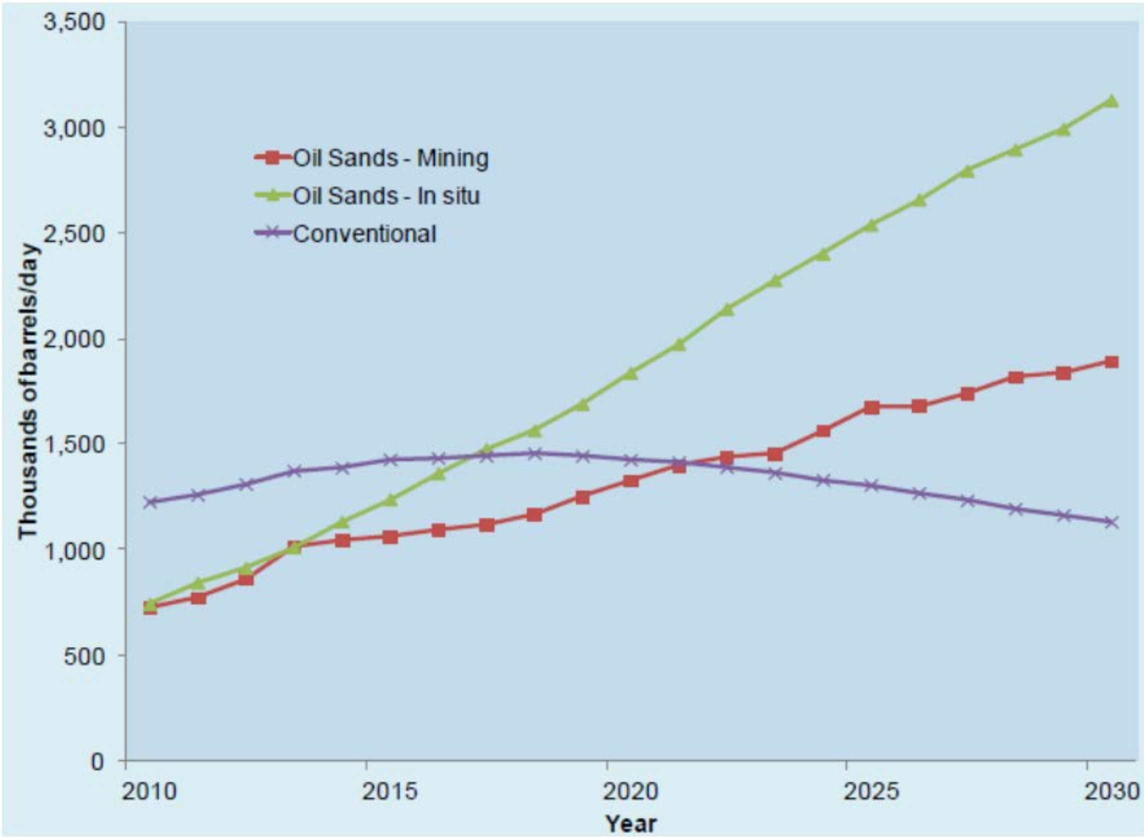
APPENDIX B. CANADIAN OIL SANDS IN THE UNITED STATES

The takeaway regarding the Canadian oil sands or bitumen reserves, and if technology eventually makes carbonates commercially recoverable, is that as the transportation infrastructure, e.g., pipelines and rail, expands to accommodate increasing production, the United States will see a continuing and expanding presence of Dilbit being transported, stored, and refined in the United States.

B.1 Future Projections

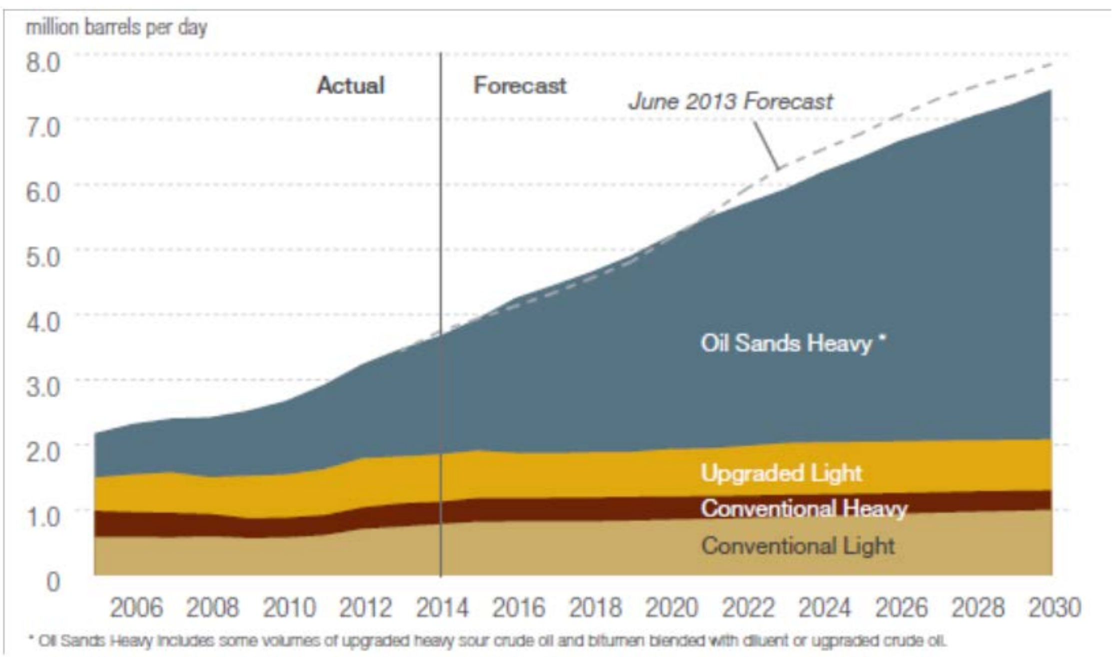
The 2013 CEPA advises that Alberta contains some 95 percent of Canada's proven oil reserves in the form of oil sands. The oil sands deposits are contained in an area of some 55,000 square miles.

Figure B-1 depicts the production forecasts for Canadian crude oils. Figure B-2 depicts an alternate view of projected production forecasts of Canadian OSPs (i.e., Dilbit and Synthetic Crude Oil (SCO)). The current demand is shown in Figure B-3. The Canadian Association of Petroleum Producers (CAPP) June 2015 report predicts that the anticipated growth in western Canadian crude oil production could potentially be absorbed by demand from a number of market regions subject to development in the North America transportation infrastructure (Canadian Association of Petroleum Producers, 2015). The U.S. Gulf Coast is a target market of considerable size and is particularly suitable for supplies from Western Canada, given the heavy oil processing capacity of the refineries located in the region. The U.S. Midwest is currently the largest market for western Canadian crude oil and could process over 400,000 bbl/d of additional volume by 2020. Refineries in Eastern Canada and the United States also indicated that they could potentially process double the current deliveries of western Canadian crude oil. The development of new rail infrastructure is planned in multiple locations some of which will have the ability to offload heavy crude oil. With the decline of Alaskan production, one of the major traditional crude sources of supply to California refineries, producers from Western Canada could deliver supplemental supplies via rail. Canadian producers also focus on opportunities to reach non-U.S., global markets, such as China, whose net oil imports are forecast to grow by almost 3 million bbl/d by 2020.



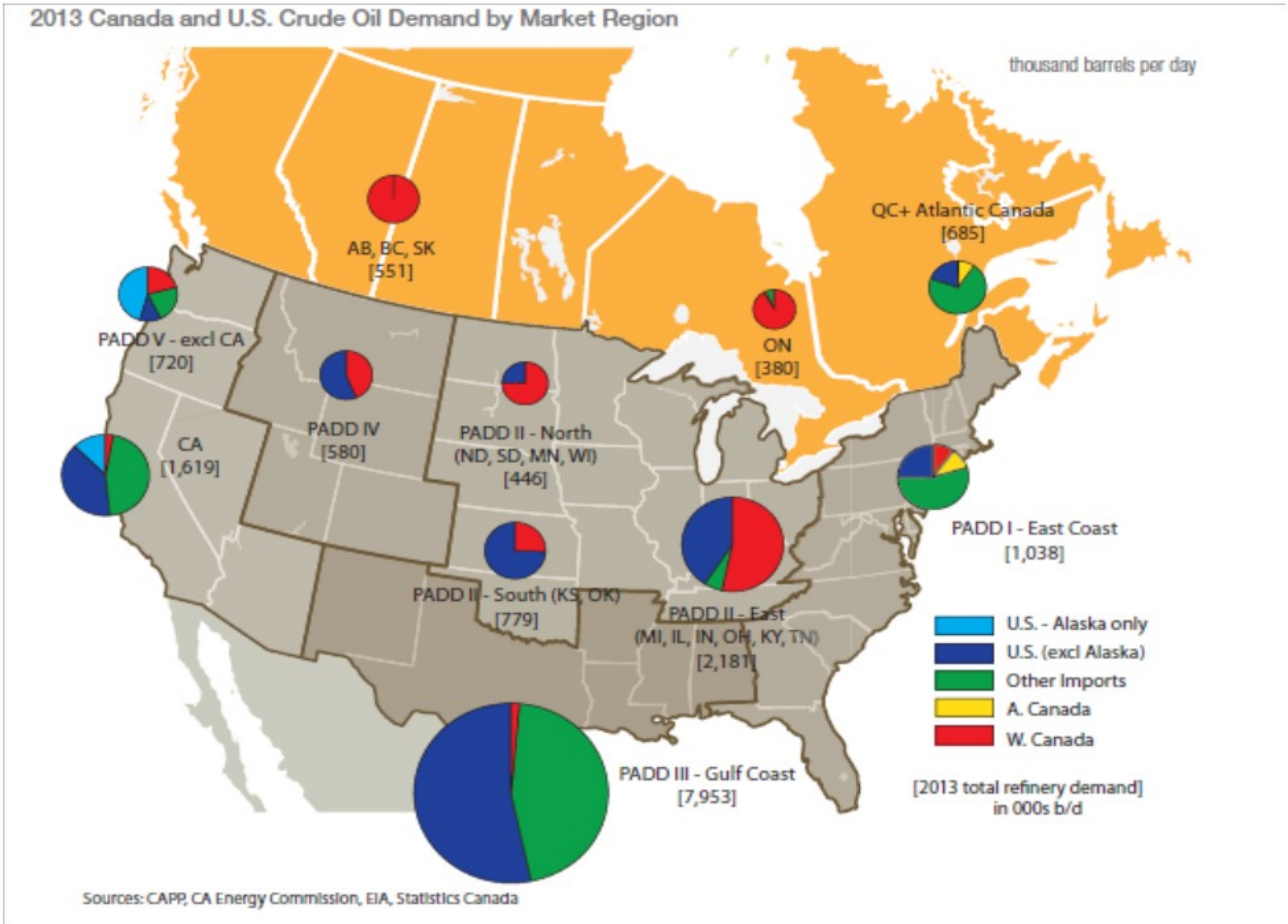
Source: (Canadian Energy Pipelines Association, 2013)

Figure B-1. Production forecasts for Canadian crude oils.



Source: (Canadian Association of Petroleum Producers, 2014)

Figure B-2. Alternate view of projected production forecasts of Canadian OSPs.



Source: (Canadian Association of Petroleum Producers, 2015)

Figure B-3. Demand for Canadian and U.S. crude oil based on the source.

B.2 Transporting and Refining Oil Sands Products

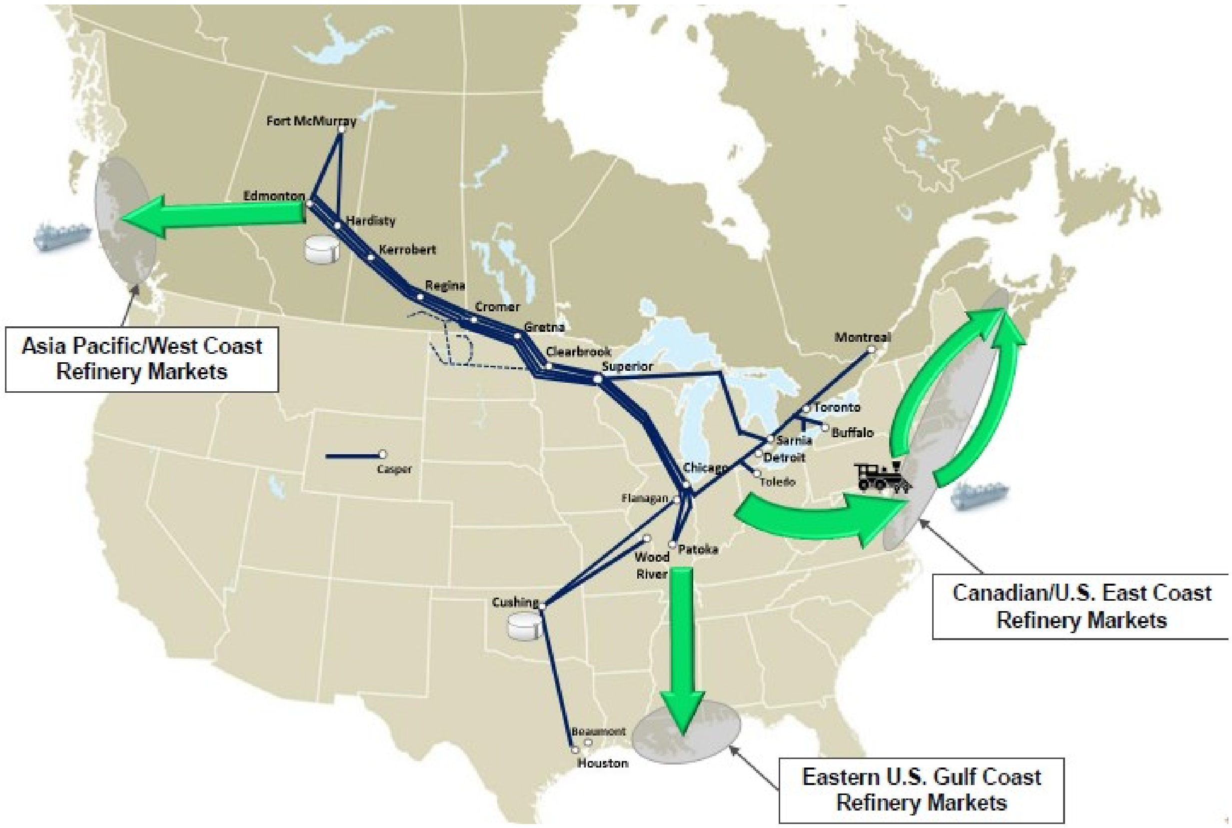
To determine geographic areas at risk, it is necessary to first evaluate the volumes, the supply and transportation logistics, bulk storage and refining locations of OSPs from their point of origin to their destination. Dagmar Schmidt Etkin of Environmental Research Consulting (ERC) states that: (Etkin, 2015)

> *"Risk involves both the probability that an incident will occur and the consequences of that incident. With respect to oil spills, risk is the probability that a spill will occur, which is in turn related to the incidence of precipitating factors, such as the probabilities of vessel groundings or train derailments, and the magnitude of impacts, which are related to spill volume, oil type, and location."*

One should be cognizant that there are restrictions to the export of U.S. crude oil. While crude oil of U.S. origin is subject to export restrictions, no such restriction applies to exports of Canadian oil through U.S. ports, as long as the exporters can show that no U.S. oil was blended in the product. Shippers who want to export Canadian oil from U.S. ports still have to apply for export licenses from the Department of Commerce; these licenses can and have been granted in the past.

B.2.1 Proposed Supply of Canadian Crude to Three U.S. Coasts

The following figure is taken from an Enbridge presentation given by Mr. J. Richard Bird, Enbridge Executive Vice President, Chief Financial Officer & Corporate Development, at a London Energy Conference (Bird, 2013). The figure depicts the proposed supply of Canadian crude, including oil sands crude, to the three U.S. coasts, providing crude oil to U.S. refineries and export potential to Europe and Asia.



Source: (Bird, 2013)

Figure B-4. Proposed supply of Canadian crude to refinery markets.

B.2.2 Growth of Non-OPEC Oil Supply

Non-OPEC oil supply is expected to grow by 6.2 million bbl/d to 60.9 million bbl/d in 2019 from 2013, at an annual average of 1.0 million bbl/d. More than half of the non-OPEC growth comes from North American Light Tight Oil (LTO); e.g., unconventional oil, and Canadian oil sands production, offsetting declines at mature fields elsewhere. Recent data shows that Canada has seen the largest increase in crude production among the non-OPEC countries. Much of the current and projected growth results from a strong increase in bitumen production from Alberta's oil sands. In 2012, production from oil sands accounted for nearly 60 percent of Canada's oil output, a proportion that has increased steadily.

According to Maude Barlow, Canada exports approximately two-thirds of its oil, including Alberta tar sands crude, to the United States (Barlow, 2014). The amount of Canadian tar sands crude refined in the U.S. grew almost five-fold between 2000 and 2010, and another 40 percent between 2010 and 2012. The number of

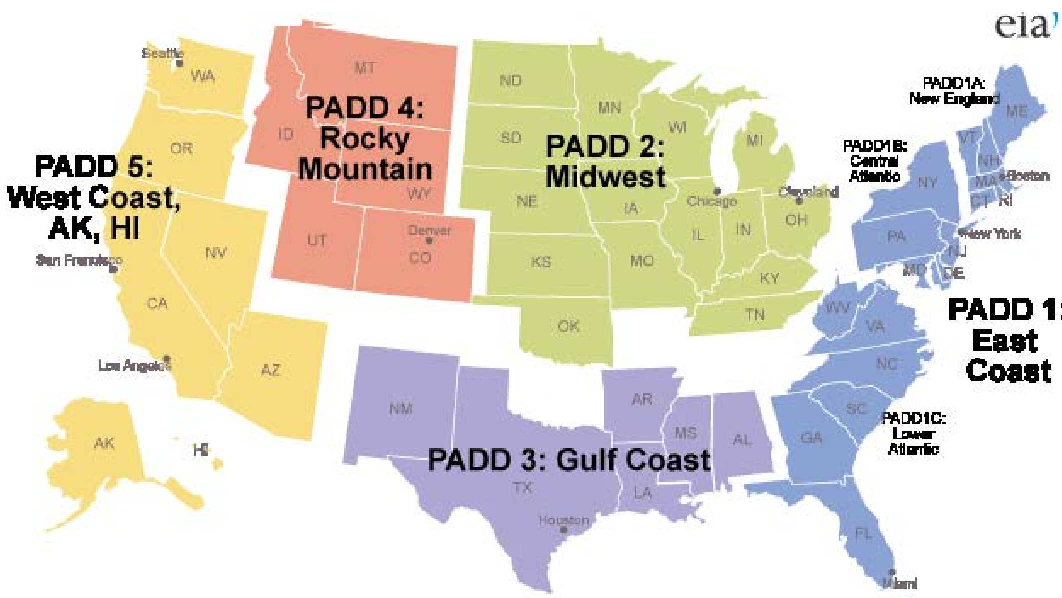
U.S. refineries processing tar sands bitumen increased from 57 to 66. The U.S.-based Natural Resources Defense Council says that, by 2020, almost one-fifth of the gasoline supply in the Northeast and the Mid-Atlantic states could be derived from tar sands crude.

The NOAA study stated that (NOAA, 2013):

> *"With the rapid growth of oil sands products in Alberta, production is expected to grow from 1.25 million barrels per day (mbl/d) in 2011 to around 3.75 mbl/d by 2030, an average annual growth rate of 11.5 percent (Canadian Province of Alberta [AB], 2012; Canadian Association of Petroleum Producers [CAPP], 2012). The majority of oil sands products transported to market will be via existing and proposed pipelines; however, a sharp increase in the use of rail can be expected while new pipelines are constructed to match the increasing production of oil sands products (CAPP, 2012; CNEB, 2009; CNEB, 2006)."*

B.2.3 Petroleum Administration for Defense Districts (PADDs)

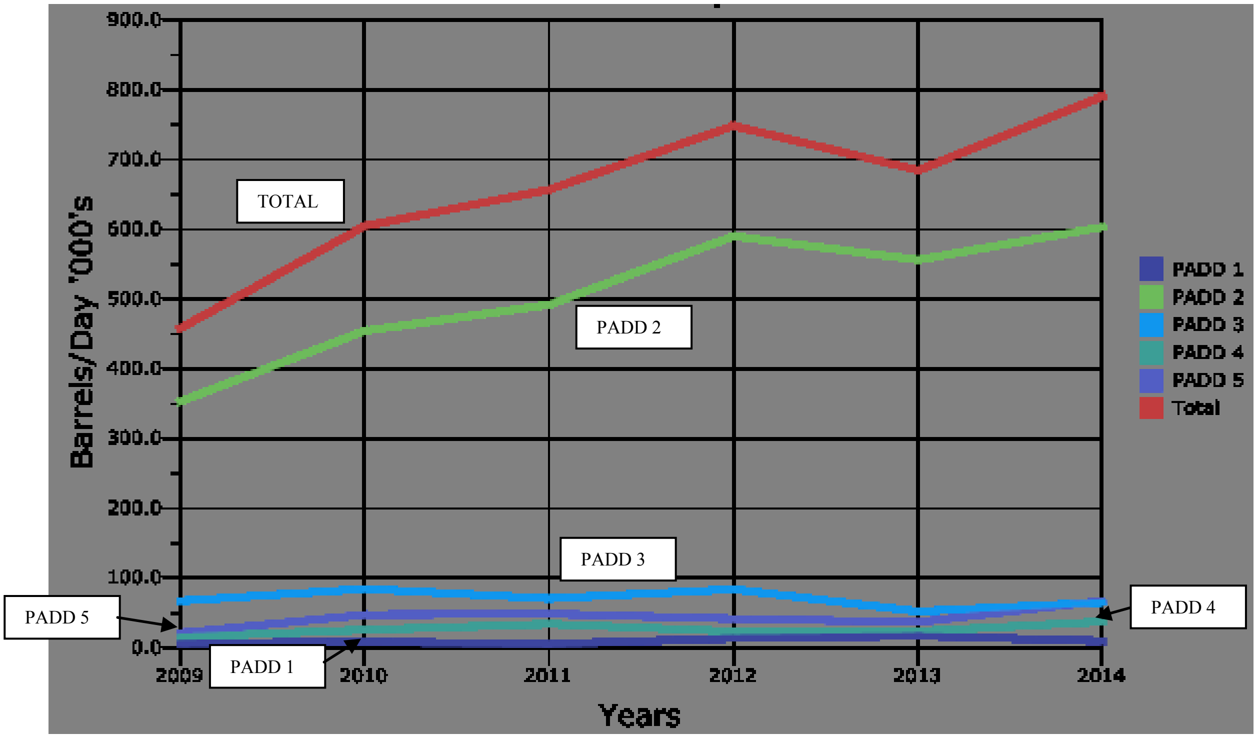
As of the 4th quarter of 2014, the U.S. PADD II region (i.e., the Midwest) was the largest recipient (74.6 percent) of oil shipments, followed by PADD III (Gulf Coast states, 10.4 percent), PADD V (West Coast, 7.8 percent), PADD I (East Coast, 4.9 percent), and PADD IV (Rocky Mountain states, 2.3 percent). The largest markets for synthetic crude oil in the United States were PADD II (75 percent) and PADD IV (8 percent). The following figure shows the five PADDs.



Source: U.S. Energy Information Administration

Figure B-5. Petroleum Administration for Defense Districts.

The following figure shows the volumes of Canadian OSPs that are exported to the United States. The data for the chart is based upon statistics produced by the Canadian National Energy Board (NEB).



Source: (Canadian National Energy Board (NEB), n.d.)

Figure B-6. Canadian bitumen export destinations.

The chart shows that the largest volume of Bitumen & Blended Bitumen exported to the United States is destined for the Midwest PADD 2, Great Lakes region. Although not as significant in volume as the Midwest PADD 2, the West Coast PADD 5, has seen a 242 percent increase in OSP destinations in 2014 from 2009 levels. The total volumes of Bitumen being exported from Canada to the United States in 2014 increased by 76 percent from the volumes exported in 2009. Thus, an increasing proportion of tar sands bitumen production is being sent to U.S. refineries that are specially equipped to refine bitumen. By evaluating the origin of OSPs and their eventual destinations in the United States, it is clear that every geographic area of the United States has the potential risk of an OSP spill incident. The risk primarily arises from pipelines and rail during shipment and eventually bulk storage facilities and refineries. The Great Lakes Commission advises that in 2009 there were 26 facilities equipped to process OSPs in the Midwest and 12 of these are in the Great Lakes states (Great Lakes Commission, 2015a). The following figure shows a map of U.S. and Canadian crude oil pipelines and refineries.

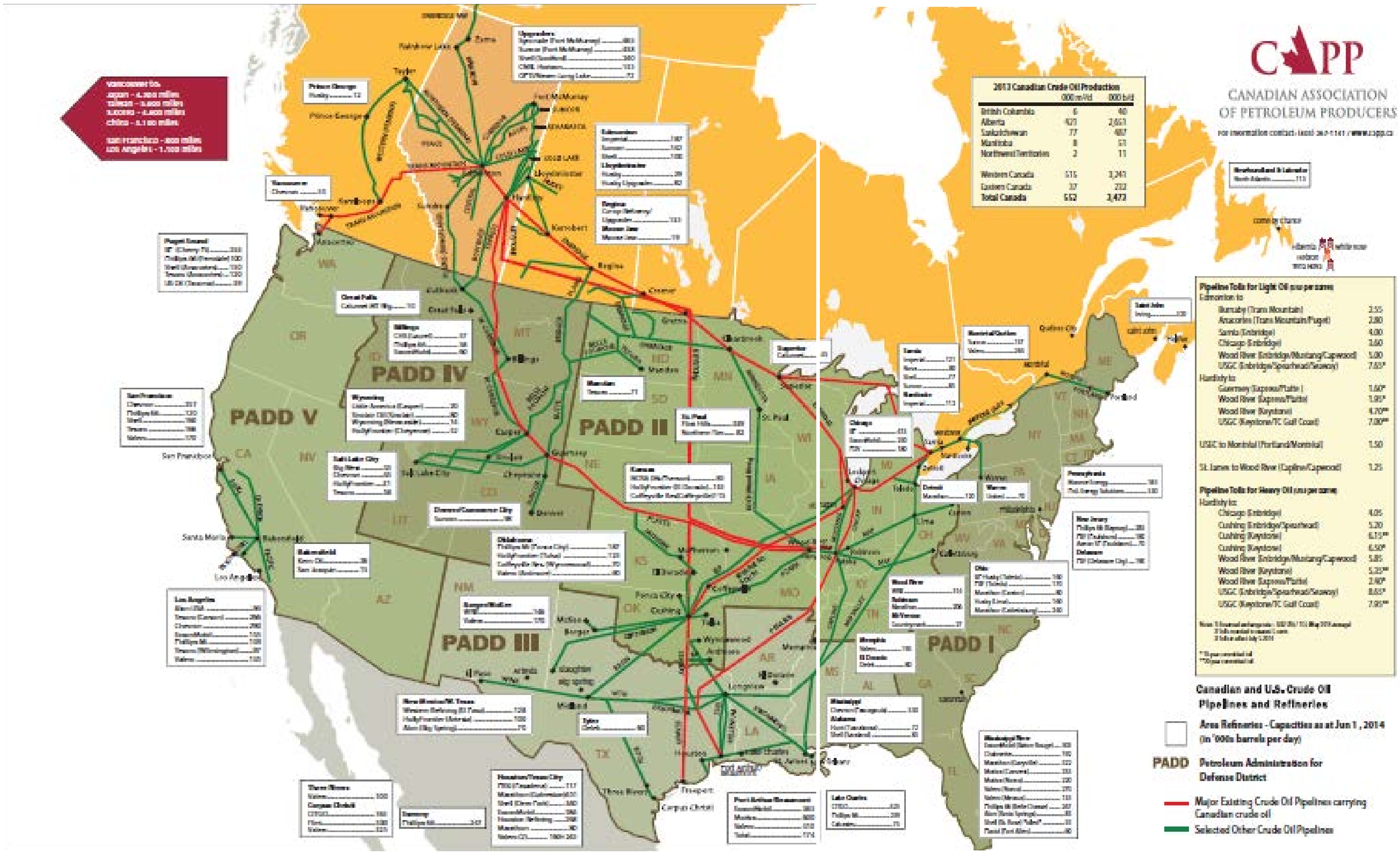


Figure B-7. Map of crude oil pipelines and refineries in the United States and Canada.

Whereas, the NOAA study (NOAA, 2013) focuses primarily on Dilbit, it is important to note that Synthetic Crude Oil, a derivative of bitumen, is also exported to the United States. A proportion of tar sands bitumen is upgraded in plants in Alberta, Canada at special refineries known as upgraders. These refineries essentially strip much of the carbon from the bitumen and produce a light synthetic crude oil (known as Syncrude, an SCO), which can then be sold to most refineries for further processing into transportation fuels and other products.

The following synthetic crude export table shows the considerable increase in Syncrude exports from Canada into the United States. Overall, Syncrude has increased 61.5 percent from 2009 to 2014; with PADD 2, Great Lakes seeing a 65.5 percent increase. Most refineries can handle Syncrude, which is a lighter oil than the dense Dilbit.

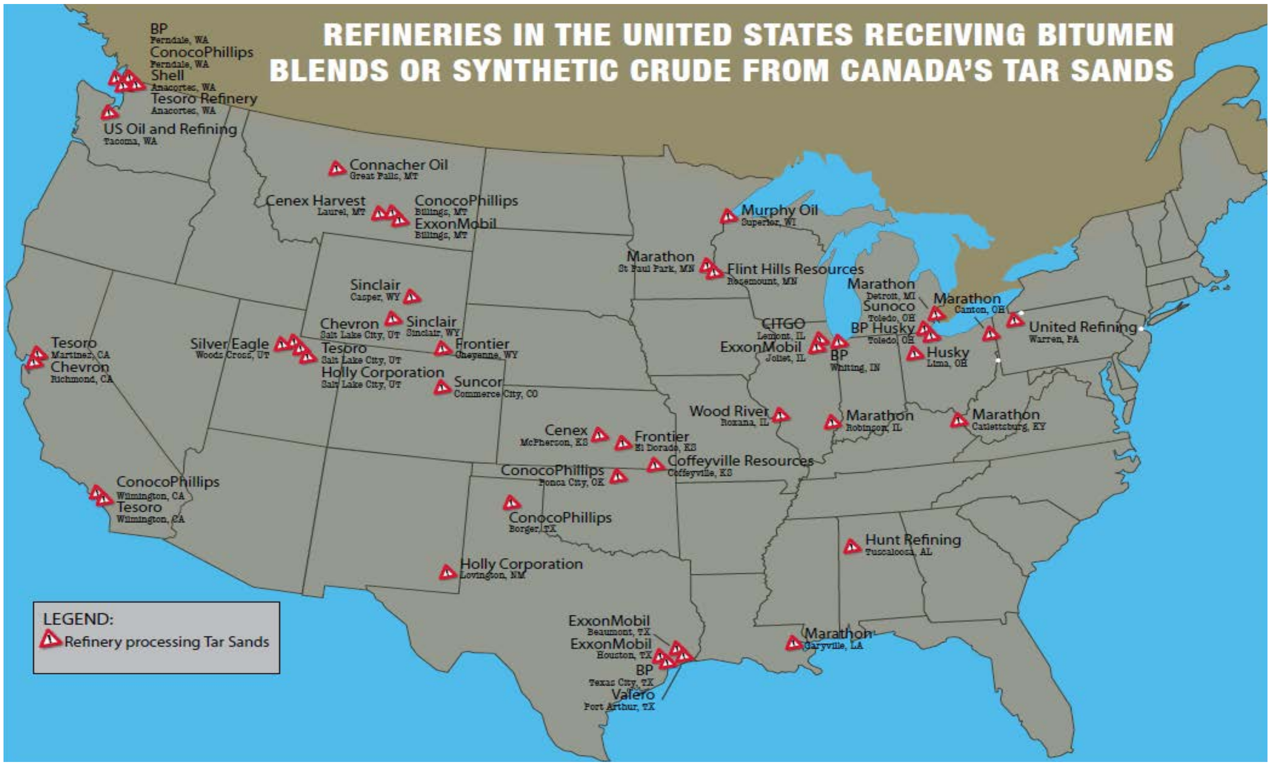
Table B-1. Synthetic crude oil exported to the United States.

PADD	2009 Average Bbls/Day	2010 Average Bbls/Day	2011 Average Bbls/Day	2012 Average Bbls/Day	2013 Average Bbls/Day	2014 Average Bbls/Day
PADD I	6,702	3,615	4,779	5,397	8,238	16,091
PADD II	275,801	245,079	285,122	348,515	397,438	456,569
PADD III	17,499	1,325	166	6,291	3,975	42,680
PADD IV	30,184	40,029	23,468	43,411	38,577	48,585
PADD V	38,606	39,373	29,329	53,915	65,361	41,809
Total Average/Day	375,138	329,421	342,840	457,552	513,579	605,732

B.2.4 Maps of U.S. Refineries

An interactive map by Oil Change International depicts U.S. refineries (Oil Change International, 2012)[3]. Clicking on a refinery location displays the usage of oil sands for that refinery on their site. However, the data is from 2012. The map in Figure 21 depicts the U.S. refineries that receive and refine bitumen blends or synthetic crude from Canada's tar sands. Again, this map has dated information and additional refineries now receive Dilbit. For example, the map does not show the Dilbit processing refineries in the Philadelphia, PA and the Wilmington/Delaware City, DE areas.

[3] http://refineryreport.org/refineries.php

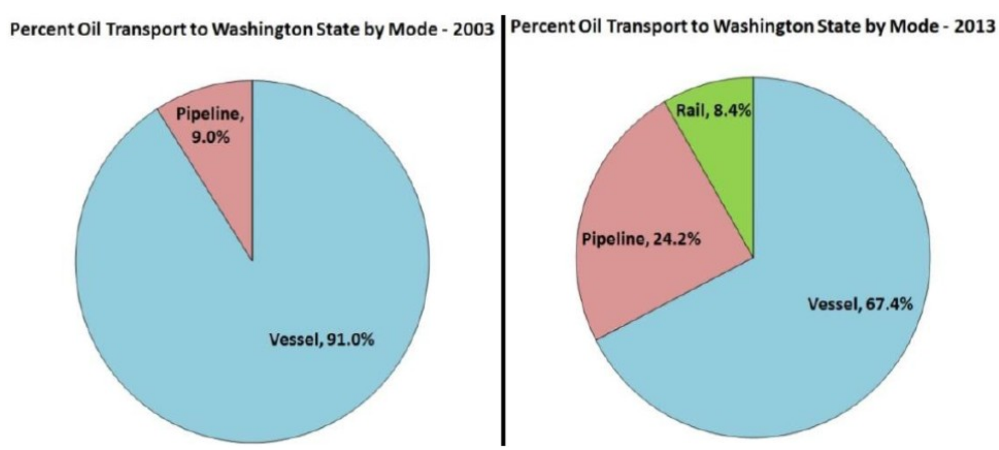


Source: (Oil Change International, 2012)

Figure B-8. Refineries in the U.S. receiving bitumen blends or synthetic crude from Canada's tar sands.

B.2.5 Routes and Nodes of Transportation of Dilbit

While some of this new North American crude oil from the Alberta tar sands territory is moved by pipeline, much is transported by tank cars. Freight trains exclusively hauling 100+ tank cars are called unit trains (Washington State Dept. of Ecology, 2015). The following figure shows the Comparison between Oil Transport Modes in Washington 2003 and 2013 and verifies the increased use of tank cars in the supply chain.



Source: (Washington State Dept. of Ecology, 2015)

Figure B-9. Oil transport modes in Washington 2003 and 2013.

In a DeSmogBlog.com article, which pulls information from an Oil Change International document (Oil Change International, 2014), Ben Jervey stated that there are 13 crude-by-rail terminals in California, Oregon, and Washington. Four of these terminals are expanding their capacity and 11 additional terminals are planned or under construction. Rail terminals are proliferating due to a lack of pipeline capacity. West Coast refineries dedicate a larger proportion of refining capacity for heavy tar sands processing than East Coast refineries. Additionally, three proposals in southern Washington State have the potential to unload tar sands crude from trains onto tankers for export to Asia or refineries on the California coast (Jervey, 2014).

Refining capacity in Washington totals 643,000 bbl/d. The state's five refineries have been primarily supplied with Alaskan production delivered by tanker but production from this source continues to decline. At 515,000 bbl/d in 2013, Alaskan production is approximately a quarter of the peak levels achieved in 1988. Note that the state's supplies could rebound as the repeal of a production tax triggers investments, which may boost output by at least 90,000 bbl/d within four years. However, in the meantime, Washington refineries increasingly depend on foreign imports; some refineries also recently have been able to access some of the growing crude oil production supply in North Dakota through the use of rail.

In 2013, Washington refineries received 223,000 bbl/d of foreign imports, of which Canada supplied 68 percent. Saudi Arabia and Russia are the second and third main suppliers with 14 percent and 3 percent shares of the market, respectively. Results from CAPP's refinery survey indicate crude oil demand from Western Canada will increase by 133,000 bbl/d from current levels, which translates to an 88 percent increase. This growth in demand relies on the successful construction of proposed rail or pipeline projects that would reach the West Coast.

A few refineries began investing in rail offloading facilities in recent years in order to access growing supplies of crude oil from North Dakota and Western Canada. All the refineries in Washington either are already receiving some crude shipments by rail or have plans to do so by the end of the year. The following figure shows PADD V (Washington) crude oil receipts from Western Canada.

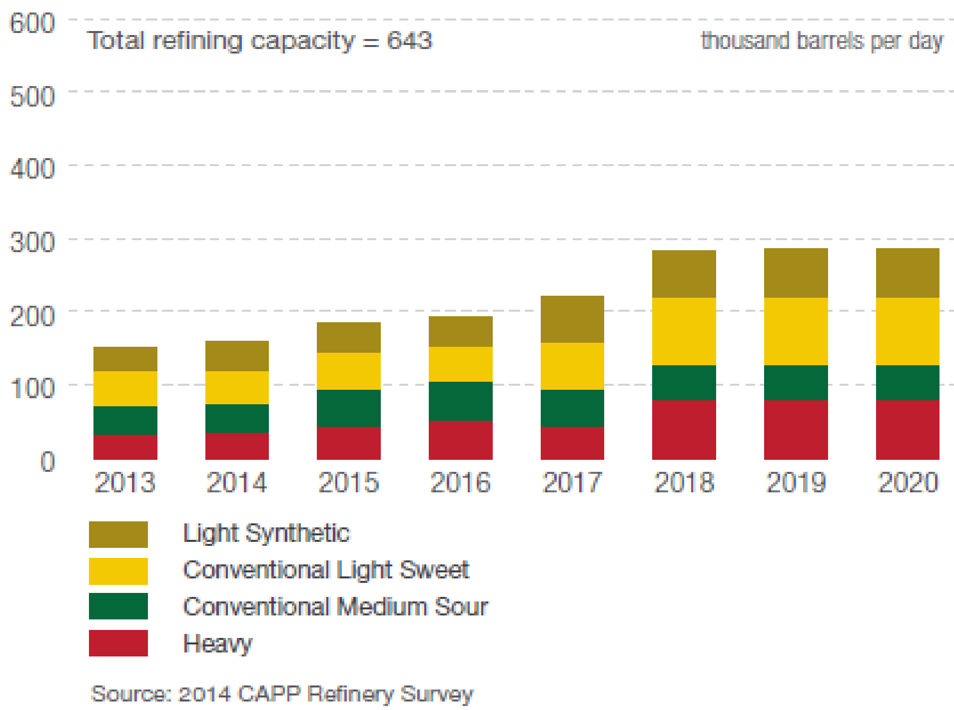


Figure B-10. PADD V (Washington): Crude oil receipts from Western Canada.

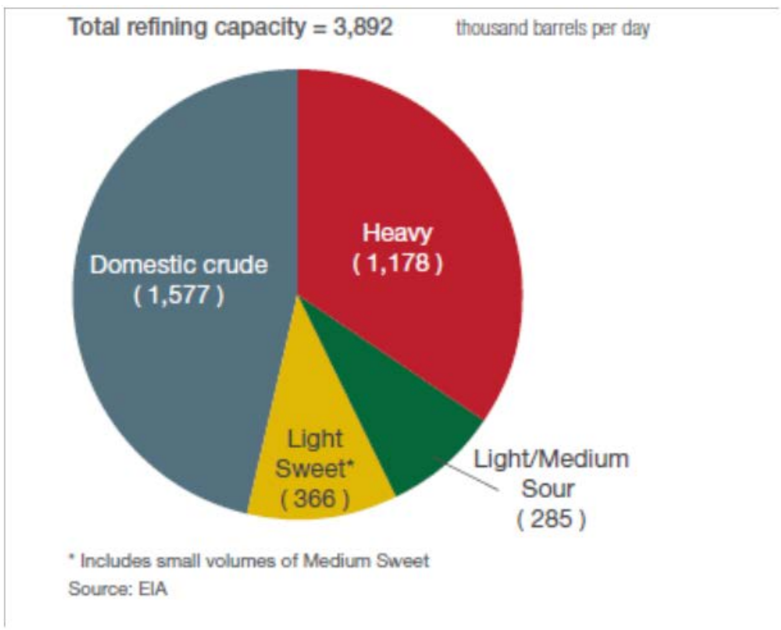
The Rocky Mountains divides PADD V (West Coast) from the rest of the United States. This geographical isolation affected the development of crude supply sources to the region. The states in PADD V that have refineries are Alaska, California, Hawaii, and Washington. These refineries are located in close proximity to production in California and Alaska and also have good access to tankers that can import crude from more distant regions. The region has a 3.1 million bbl/d of refining capacity. Foreign imports typically supply almost 50 percent of the crude oil feedstock demand and this share is expected to supplement the declining production from Alaska.

The Great Lakes region is strategic to the connection between key United States and Canadian extraction sites and refineries and ports on the East, West, and Gulf Coasts. The increase in oil production has resulted in a dramatic surge in the movement of oil through the Great Lakes basin, which has further increased environmental, public health, and safety concerns among regulatory bodies. All the modes of crude oil transport—pipelines, rail, barge and trucks—as well as the transshipment locations where oil is moved from one mode of transport to another, pose potential risks.

According to the National Petroleum Council (NPC), historically, the Mid-West has been and will continue to be the most critical entry point for Canadian imports to the United States (National Petroleum Council (NPC), 2011). With only marginal refined product demand growth in North America over the next two and a half decades and limited expected refining capacity additions in the Mid-West, incremental Canadian imports will have to find an outlet beyond the Mid-West. While the Mid-West has been able to absorb incremental imports from Canada by displacing foreign imports from the U.S. Gulf Coast (USGC) import corridor, the ability to curtail additional foreign imports will be outpaced by the volume growth of incremental imports from the North. Throughput along the Western Canadian Import corridor is expected to double over the next 25 years; this is contingent on a conservative assumption that Western Canadian supply penetrates further into the Eastern Canadian market via the Mid-West.

Given the Mid-West's location, Eastern Canada, Mid-Continent, and the Rockies are its only viable export corridors. The Rockies and existing USGC corridors have limited capacity and are fully utilized. The capacity along the export corridor from the Mid-West to the Rockies is expected to increase in the future, largely in response to the growing crude supply from North Dakota; however, infrastructure growth opportunities along this corridor are limited by the small size of the Rockies refining market, which has traditionally been supplied from Canada. This limitation implies that the inbound crude from the North to the Mid-West must penetrate further south to the Mid-Continent and ultimately to the large USGC refining market where the potential to displace incremental foreign crude remains high.

Over 3.9 million bbl/d of refining capacity is located in PADD II. In 2013, these refineries received 1.8 million bbl/d of foreign sourced crude oil, almost all of which was from Western Canada and were predominantly heavy supplies of oil sands. The following figure shows 2013 PADD II foreign sourced supply by type and domestic crude oil.



Source: (Canadian Association of Petroleum Producers, 2014)

Figure B-11. 2013 PADD II: Foreign sourced supply by type and domestic crude oil.

PADD II (Great Lakes Region) can be further divided into the Northern, Eastern, and Southern PADD II states. The primary market hubs within PADD II are located at Clearbrook, Minnesota for the Northern PADD II states; Wood River-Patoka, Illinois area for the Eastern PADD II states; and Cushing, Oklahoma for the Southern PADD II states. The Midwest region is currently Canada's largest market. However, this traditional market is becoming saturated as evidenced by the high level of inventories from growing domestic production and imports from Western Canada.

The total refining capacity in Eastern PADD II is over 2.5 million bbl/d from 14 refineries located throughout the six states of Michigan, Illinois, Indiana, Kentucky, Tennessee, and Ohio. In 2013, this market collectively imported over 1.3 million bbl/d of crude oil supplies, of which 97 percent were sourced from Western Canada. Imports of heavy western Canadian crude oil are estimated to increase from current levels by over 400,000 bbl/d in 2020. A number of previously announced refinery projects designed to

increase heavy oil processing capacity at various refineries have recently been completed. The following figure shows PADD II (East) crude oil receipts from Western Canada.

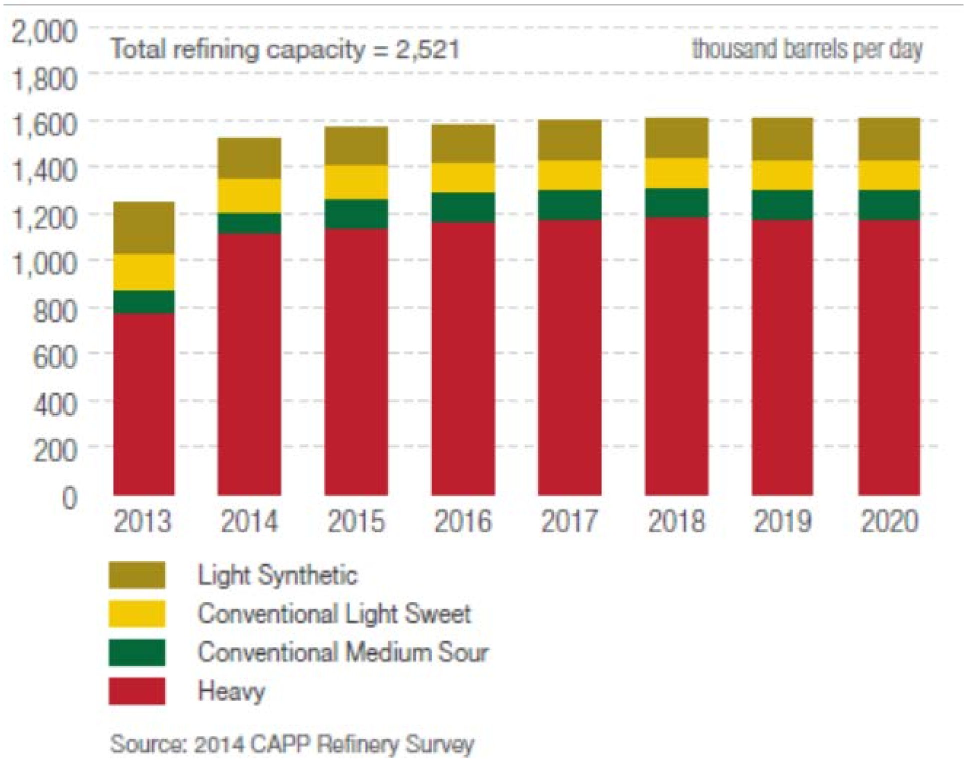


Figure B-22. PADD II (East): Crude oil receipts from Western Canada.

In Northern PADD II there are two refineries located in Minnesota, a refinery in Wisconsin and another refinery in North Dakota. The existing four refineries have a combined capacity of 564,500 bbl/d. Construction on a new refinery in North Dakota was scheduled for completion by the end of 2014. This refinery has a designed capacity of 20,000 bbl/d and is intended to process U.S. crude oil. All seven refineries in Southern PADD II are located either in Kansas or Oklahoma and account for a combined capacity of 807,000 bbl/d. U.S. domestic production satisfies the majority (56 percent) of the refinery feedstock demand in these two regions, while almost all of the foreign imports into these two regions are sourced from Western Canada. Most, or 81 percent, of the 538,000 bbl/d of western Canadian crude oil imports were heavy oil supplies. The following figure shows PADD II (North and South) crude oil receipts from Western Canada.

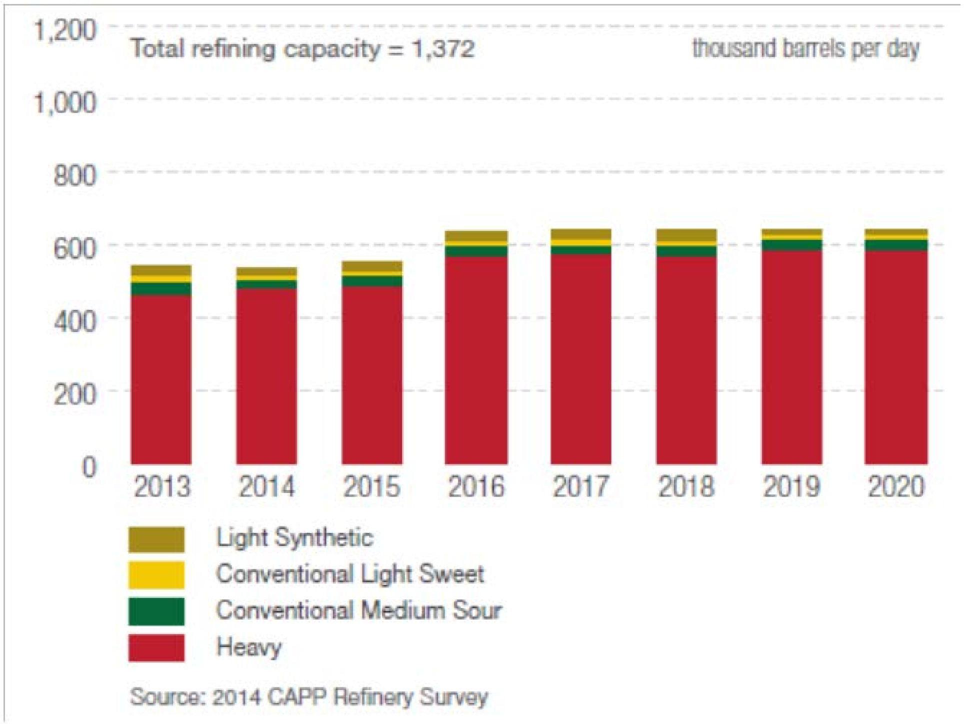


Figure B-33. PADD II (North and South): Crude oil receipts from Western Canada.

B.2.5.1 Pipelines

Historically, pipelines have been the preferred mode for transporting petroleum products. More oil is transported through the Great Lakes-St. Lawrence River basin by pipeline than by any other mode. Approximately 70 percent of oil sands products produced in Alberta is shipped to U.S. refineries via pipeline. Pipelines are, on average, $5 to $10 per barrel cheaper than rail. As a result, the increasing production of oil sands crude in Alberta likely will drive industry toward new pipeline construction to support future transportation to the U.S. Midwest for refining. Recent pipeline failures have raised awareness of pipeline safety and drawn attention to the vulnerability of the Great Lakes to pipeline spills. These spills have also prompted response agencies to evaluate the state of preparedness within their jurisdiction and to identify areas where these programs can be improved.

> *"The increased production in Alberta has been the impetus for several new projects. The Enbridge 9 pipeline reversal project from Sarnia, Ontario, to Montréal, Québec, is now in its final phase. When completed, it will allow the transportation of crude oil to Montréal, where it will be either refined or shipped by tanker to a refinery in Québec City. The TransCanada Keystone XL project would enable the transportation of crude oil from the Fort McMurray region in Alberta to refineries in Montana and Oklahoma. This project is awaiting presidential approval, and a decision is expected by the end of 2014. TransCanada is also planning on converting the Energy East pipeline from a gas to an oil transportation line that would bring the crude oil from Alberta to Cacouna, Québec, to be exported by tanker. Another exportation project is the Kinder Morgan Trans Mountain pipeline (Alberta to the Canadian west coast)."*

The crude oil from the Alberta oil sands is mostly transported by pipeline through the Great Lakes basin, and a large quantity of it is refined around the lakes.

Approximately 2.5 million miles of pipelines transport roughly two-thirds of domestic energy supplies throughout the United States. In Canada, a network of gathering and feeder pipelines collects Dilbit and synthetic crude oil from Alberta's northern oil sands deposits (primarily Athabasca, Cold Lake, and Peace River), and feeds the oil into two main collection points for southbound deliveries in Alberta: Edmonton and Hardisty. Most of the feeder pipelines move Dilbit and synthetic crude oil southbound and diluent northbound; few pipelines move product laterally within the oil sands region.

From Edmonton and Hardisty, four main transmission pipelines move Dilbit and synthetic crude oil, as well as conventional crude oil and various oil and natural gas productions, to refineries and destinations across North America. These main transmission systems are as follows:

1. Enbridge has a complex existing system of pipelines, which takes crude oil from Edmonton and Hardisty, east to Montreal and south as far as the Gulf Coast of the United States. Enbridge also has a northbound pipeline, which takes diluent from refineries in Illinois and other Midwestern states to Edmonton.
2. Kinder Morgan has the Trans Mountain Pipeline, which takes crude oil from Edmonton over the Rocky Mountains to the west coasts of British Columbia and Washington State.
3. Kinder Morgan also has a system of pipelines that takes crude oil from Hardisty, south to Casper, Wyoming, and then east to Wood River, Illinois.
4. TransCanada Corporation has the Keystone Pipeline system. Phase 1 currently takes crude oil from Hardisty, south to Steele City, Nebraska, and then east to Wood River, Illinois. The existing Phase 2 moves crude oil from Steele City to Cushing, Oklahoma.

The growing supply of crude oil from Western Canada is rapidly filling the existing pipeline capacity and extended timelines for regulatory approvals, combined with other uncertainties, have affected the evolution of the transportation network. Other forms of transport, such as railways, barges, and marine tankers are quickly becoming additional means to distribute increasing volumes of western Canadian crude oil to markets throughout North America and beyond. The existing pipeline infrastructure and the proposed pipeline projects, however, will continue to provide essential take-away capacity from the Western Canada Sedimentary Basin (WCSB) to all key markets. There are a number of pipeline projects in the regulatory process or being considered that could deliver large volumes to the East Coast, West Coast, and U.S. Gulf Coast. Figure B-44 shows all proposed Canadian and U.S. crude oil pipelines. The map shows current and proposed Canadian and U.S. oil pipelines which carry tar sands oils. The map includes the proposed TransCanada Keystone XL pipeline, which would cross the United States-Canadian border and six states (Canadian Association of Petroleum Producers, 2014).

Source: (Canadian Association of Petroleum Producers, 2014)

Figure B-44. Current and proposed Canadian and U.S. oil pipelines that carry oil sands.

The U.S. Energy Information Administration advises that: (U.S. Energy Information Administration, 2014)

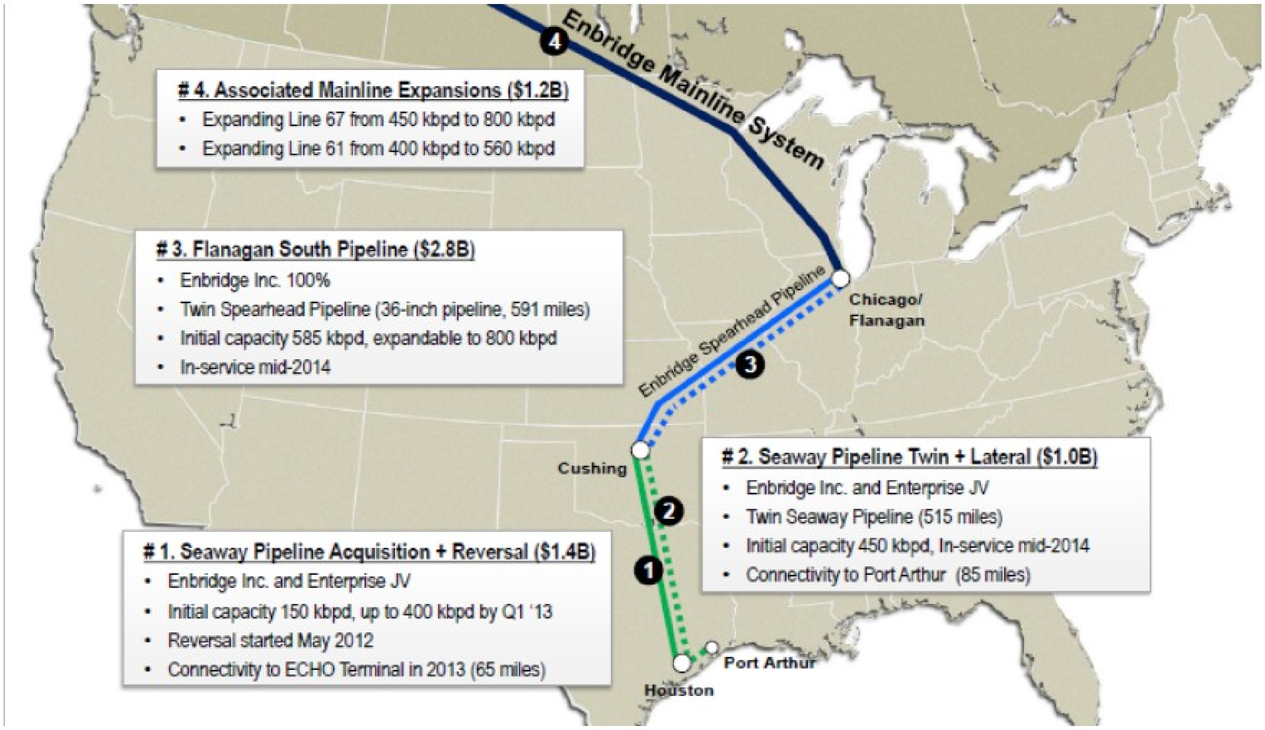
> *"The Canadian Mainline and the U.S. Mainline (Lakehead) pipeline networks, transports 2.5 million bbl/d of petroleum and other liquids from western Canada, Montana, and North Dakota to western Canada, the U.S. Midwest, and eastern Canada. The Lakehead system includes the Alberta Clipper pipelines connecting Hardisty, Alberta to Superior, Wisconsin at a capacity of 450,000 bbl/d. An expansion project scheduled to be completed by 2015 will increase the capacity to 800,000 bbl/d. The Southern Lights pipeline laid parallel to the Alberta Clipper, but it runs in the opposite direction to transport lighter hydrocarbons back to Alberta for use as a diluent in transporting and processing bitumen. Along with other smaller pipelines on both sides of the border, large pipeline systems transport 68% of the oil exported from western Canada.*
>
> *The Trans Mountain Pipeline System is the only pipeline system that transports crude oil to the west coast of North America. The pipeline originates in Edmonton, Alberta and travels to various marketing and refining stations near Vancouver, British Columbia. Its*

> *capacity is rated at 300,000 bbl/d. The cross-border Express pipeline (280,000 bbl/d) connects with the smaller Platte pipeline in Casper, Wyoming and then travels to Illinois.*
>
> *The 2,600-mile Keystone pipeline with a capacity of 590,000 bbl/d runs from Hardisty, Alberta to Manitoba and crosses the border to Steele City, Nebraska where it splits into two systems servicing the U.S. Midwest and U.S. Gulf Coast."*

The U.S. Energy Information Administration continues to advise that: (U.S. Energy Information Administration, 2014)

> *"The proposed Keystone XL pipeline would travel directly from Hardisty, Alberta to Steele City, Nebraska, with a capacity of 830,000 bbl/d. Because it would cross an international border, a presidential permit must be granted stating that the project is in the national interest. In May 2012, a new application for a presidential permit included alternative routes through Nebraska. The proposal awaits the administration's decision. In the interim, some of the oil from Alberta has been shipped by rail.*
>
> *While Keystone XL was initially proposed as an integrated pipeline from Canada to the U.S. Gulf Coast, a shorter section that is entirely inside the United States was pursued as a separate project when the presidential permit for the cross-border segment was not approved. The pipeline that would connect Cushing, Oklahoma with the Texas refining sector is now known as the Gulf Coast Pipeline Project, and would resolve some of the infrastructure constraints that have resulted in a glut of oil at the Cushing hub. Construction on the Gulf Coast Pipeline Project commenced in August 2012 following final approval of its permits by the U.S. Army Corps of Engineers. In January 2014, the pipeline went online operating at 520,000 bbl/d with the potential capacity of 830,000 bbl/d.*
>
> *New or expansion pipeline projects in development would ultimately increase the pipeline capacity to deliver oil from Alberta to the U.S. Midwest and U.S. Gulf Coast, servicing areas in-between."*

The Enbridge Canadian to Gulf of Mexico (GOM) pipeline project, shown in Figure B-55, commenced operation early 2015 (Bird, 2013).



Source: J. Richard Bird, Enbridge Ex-VP & CFO (Bird, 2013)

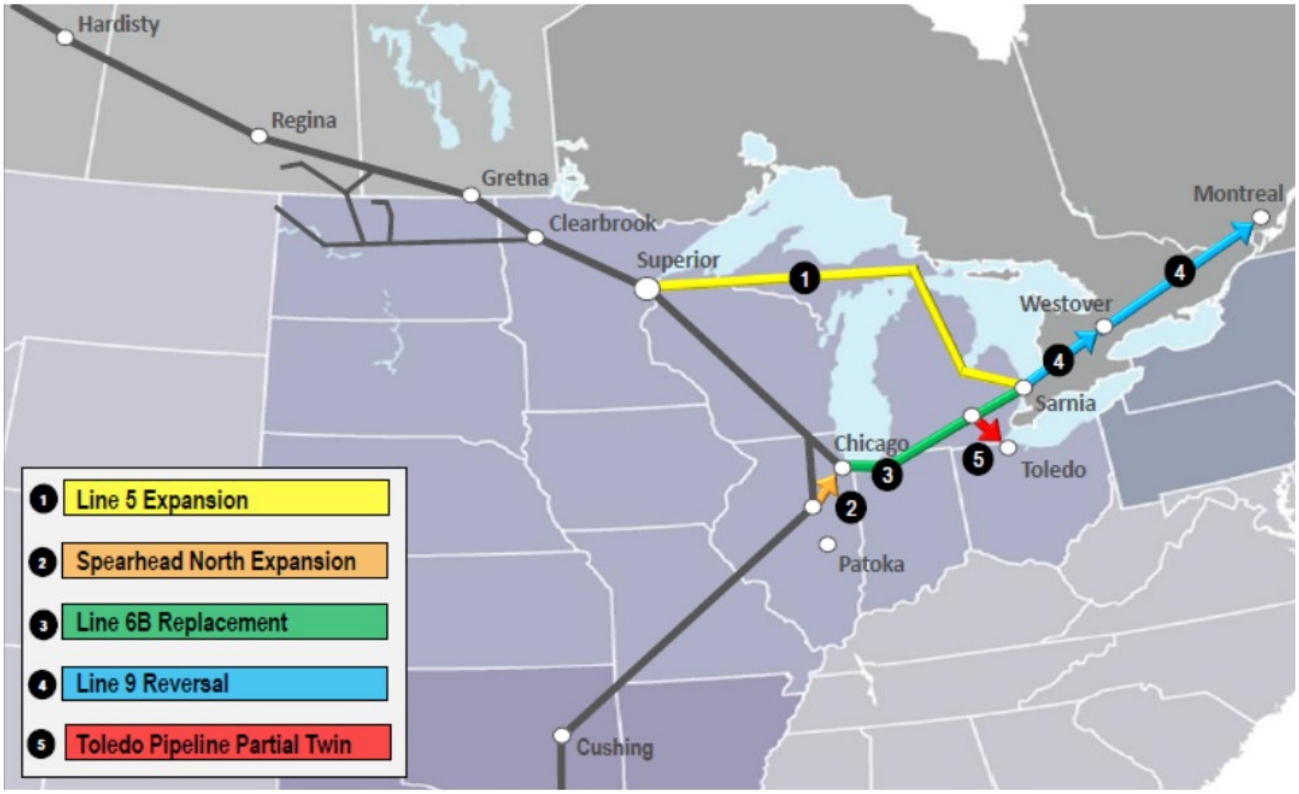
Figure B-55. The Enbridge Canadian to GOM pipeline project.

The U.S. Energy Information Administration further advises that: (U.S. Energy Information Administration, 2014)

> *"Proposed new or expanded pipelines to the U.S. West Coast are in the preliminary stages of planning and regulatory review. The existing Trans Mountain pipeline system by building a second pipeline within the same right-of-way. The expansion would increase Trans Mountain's capacity to 850,000 bbl/d. Construction is expected to begin in late 2015. The Northern Gateway Pipeline Project would end at a deepwater port in Kitimat, British Columbia and include a 525,000 bbl/d crude oil pipeline and a smaller parallel pipeline to carry condensate back to Alberta expected to begin in 2018.*
>
> *The completion of either or both of these projects would create a new export outlet for oil sands. Additional pipeline capacity to Canada's west coast would reduce Canada's overland dependence on the U.S. market while providing access to growing Asian economies in the Pacific Basin, which could have important implications for trade flows and the prices received by Canadian oil producers. The proposed west coast projects must overcome opposition, particularly due to concerns about the risk of pipeline or tanker spills in British Columbia and among affected aboriginal First Nations groups."*

In a 2014 article, Emma Lui discusses the expansion of the Alberta Clipper pipeline project, which doubles the pipeline's capacity to 800,000 bbl/d (Lui, 2014). The pipeline expansion project is expected to pave the way for more oil sands projects around the Great Lakes, including the Calumet Specialty Products-Elkhorn Industries project, which would have oil sands or fracked oil shipped across the Great Lakes.

Another project, depicted in Figure B-66, is Enbridge's Line 5, which would transport oil sands through the Straits of Mackinac, known as the heart of the Great Lakes.



Source: (Bird, 2013)

Figure B-66. Enbridge Line 5 expansion project.

B.2.5.2 Rail

Rail transport, because of its load carrying and routing flexibility, has increased in recent years due to capacity limitations in the pipeline network. The increase in rail transport is dramatic: 9,500 carloads of crude oil were carried by train in 2008 in the United States, compared with 650,000 carloads forecasted by the end of 2014. In Canada, 500 carloads were carried in 2009 and an estimated 140,000 carloads will be carried in 2014. The transportation of crude oil via rail has garnered much attention since the Lac-Mégantic incident—safety issues being addressed related to crew size and training; tank car designs; routes for trains carrying crude oil; and communications with state/provincial and local agencies. A key issue is the ability of the legal and regulatory regime to keep pace with the market-driven increase in oil being transported by rail.

Data from the U.S. Energy Information Administration states that (U.S. EIA Beta, 2014):

> *"Rapidly increasingly supply of liquid fuels from the oil sands in western Canada has far outpaced pipeline capacity and the expansion efforts of the pipeline companies. With infrastructure already in place serving the demand destinations for western Canadian crude, rail has proven to be an adequate substitute. In 2013, crude oil transported by rail reached 200,000 bbl/d, of which 128,000 bbl/d were exported to the United States. Compared to the previous year, exports by rail increased 177%. In 2013, 45% of crude*

> *exports by rail went to the U.S. Gulf Coast, 44% went to the East Coast, and 9% went to the West Coast. The Canadian Association of Petroleum Producers (CAPP) projects that by 2016, Canada will transport up to 700,000 bbl/d of crude oil by rail. Current rail loading capacity is estimated at 300,000 bbl/d and is expected to increase to 1 million bbl/d by 2015."*

Tank cars can be pressurized or non-pressurized, insulated or non-insulated, and designed for single or multiple commodities. Non-pressurized cars have various fittings on the top and may have fittings on the bottom. Some of the top fittings are covered by a protective housing. Pressurized cars have a pressure plate, pressure relief valves, and a cylindrical protective housing at the top.

The existing fleet of DOT-111 tank cars was designed in the 1960s. The Association of American Railroads (AAR) issued Casualty Prevention Circular (CPC) letter 1232 which specifies new tank car standards for transporting crude oil or ethanol. Effective October 10, 2011, new tank cars built for transporting crude oil and ethanol must include half-height head shields, thicker tank and head material, normalized steel, top fitting protection, and reclosing pressure relief devices.

Approximately 60,000 CPC-1232 tank cars and 100,000 older DOT-111 tank cars haul crude oil across North America. These cars often carry Dilbit, which is different than traditional heavy crude oil. The diluents in Dilbit are typically highly volatile substances, such as condensate from gas wells, pentanes and other light products from oil refineries or gas plants, and synthetic crude oil from oil sands upgraders. Recent tank car derailments included CPC-1232 tank cars that breached, resulting in oil spills with associated fire events.

On August 1, 2014, the U.S. Department of Transportation (DOT) published its proposed regulations governing the safety of tank cars used for transport of hazardous and volatile crude and ethanol. DOT presented three options for tank car safety standards: the Pipeline and Hazardous Materials Safety Administration (PHMSA)/ Federal Railroad Administration (FRA) Design Option; the AAR 2014 Tank Car Option; and the Enhanced CPC 1232 Tank Car. The PHMSA/FRA option would require, among other things, the following: a minimum shell thickness of 9/16 inch; top fitting protections capable of sustaining a rollover accident of nine miles per hour; and Electronically Controlled Pneumatic (ECP) brake systems installed on all cars, enabling faster braking to reduce the likelihood of cars colliding with one another. These standards would be required for all new and retrofitted tank cars in addition to the basic safety upgrades in the CPC-1232 cars that industry already agreed to.

Due to a lack of pipeline capacity out of Alberta and/or pipelines that terminate in locations that can refine tar sands oil mainly in the United States, the industry must rely on other modes of transportation; thus Canadian tar sands producers increasingly turn their attention to rail and arrange transportation contracts with Canadian rail operators. The main carriers involved with oil sands transportation are Canadian National (CN), Canadian Pacific (CP), Burlington Northern Santa Fe (BNSF), Union Pacific (UP) and CSX Transportation. The Canadian National Railway is getting a large portion of this transportation business. Canadian National not only has the infrastructure in place near Alberta's tar sands developments, but also operates 19 subsidiary railways in the United States under the Grand Trunk Corporation. Strung together, Canadian National network stretches 2,800 miles from Western Canada down to the Gulf Coast. Canadian National is the only company that can offer straight-through shipping from the tar sands to Gulf Coast refineries. Figure B-77 shows U.S. crude oil rail routes. An interactive crude by rail map by Oil

Change International depicts the railroad routes and terminals that are handling crude oil (Oil Change International, n.d.)[4]

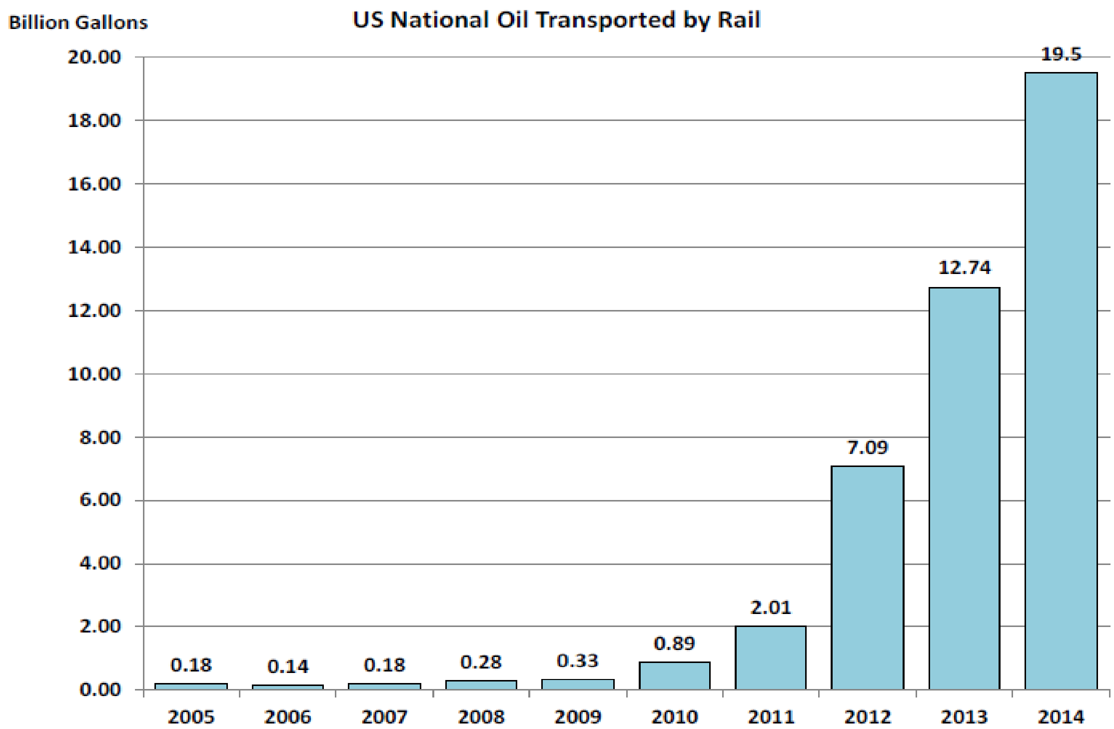
Source: Oil Change International Website (Oil Change International, n.d.)

Figure B-77. Crude oil rail routes in the United States.

Most trains are still being loaded with Dilbit because to this point, most loading terminals are still being fed by feeder pipelines or trucks that can only handle the 30 percent bitumen blend, i.e., Dilbit. Special loading and unloading facilities are necessary to handle Railbit, which is more viscous and needs to be heated in special tank cars to be unloaded. Some downstream terminals are making these investments, seeing Railbit as a viable alternative going forward. In 2013, it is estimated that between 11.8 and 12.7 billion gallons of oil were shipped by railroad through the United States. That represents a 42-fold increase in national oil transportation by rail since 2008.

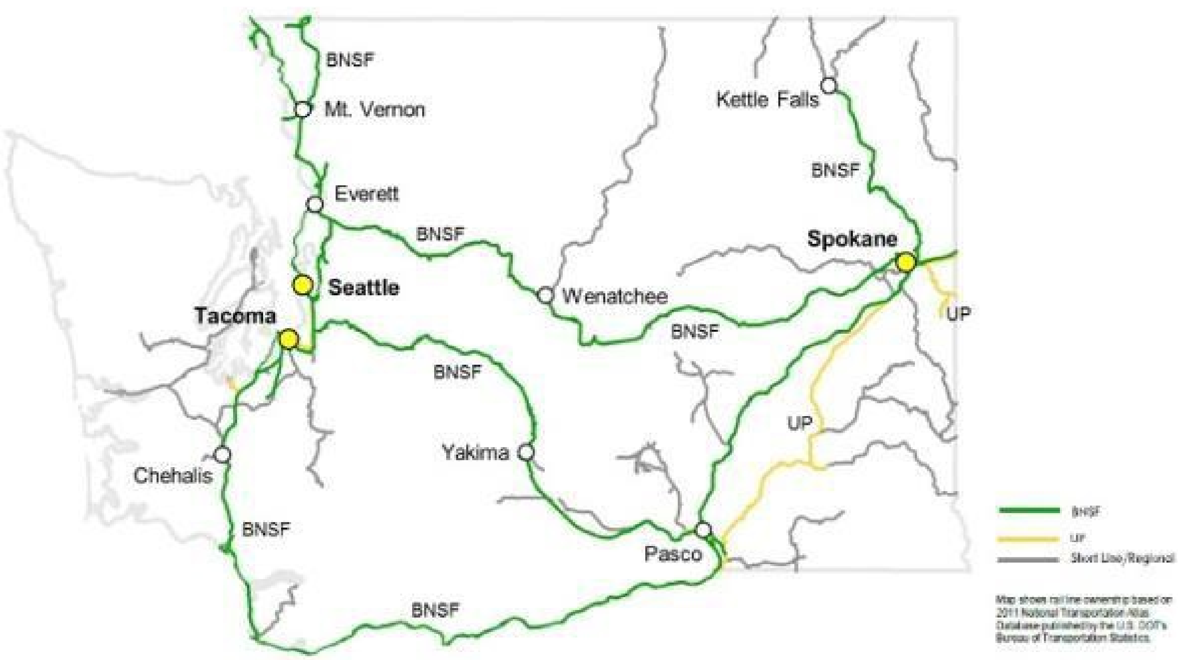
The Washington State Marine & Rail Study explains that by the end of 2014, 650,000 carloads carrying 19.5 billion gallons of crude oil were expected in the U.S. This estimation would mean that the number of crude oil-containing tank cars has increased over 108 times in the last seven years. Figure B-88 shows changes in U.S. oil transport by rail from 2005 to 2014. The map in Figure B-9 shows the primary route of rail transport of crude oil in Washington State. Figure B-20 shows the approximate cycle times and estimated costs for rail transportation to various key markets in Canada and the United States.

[4] http://priceofoil.org/rail-map/



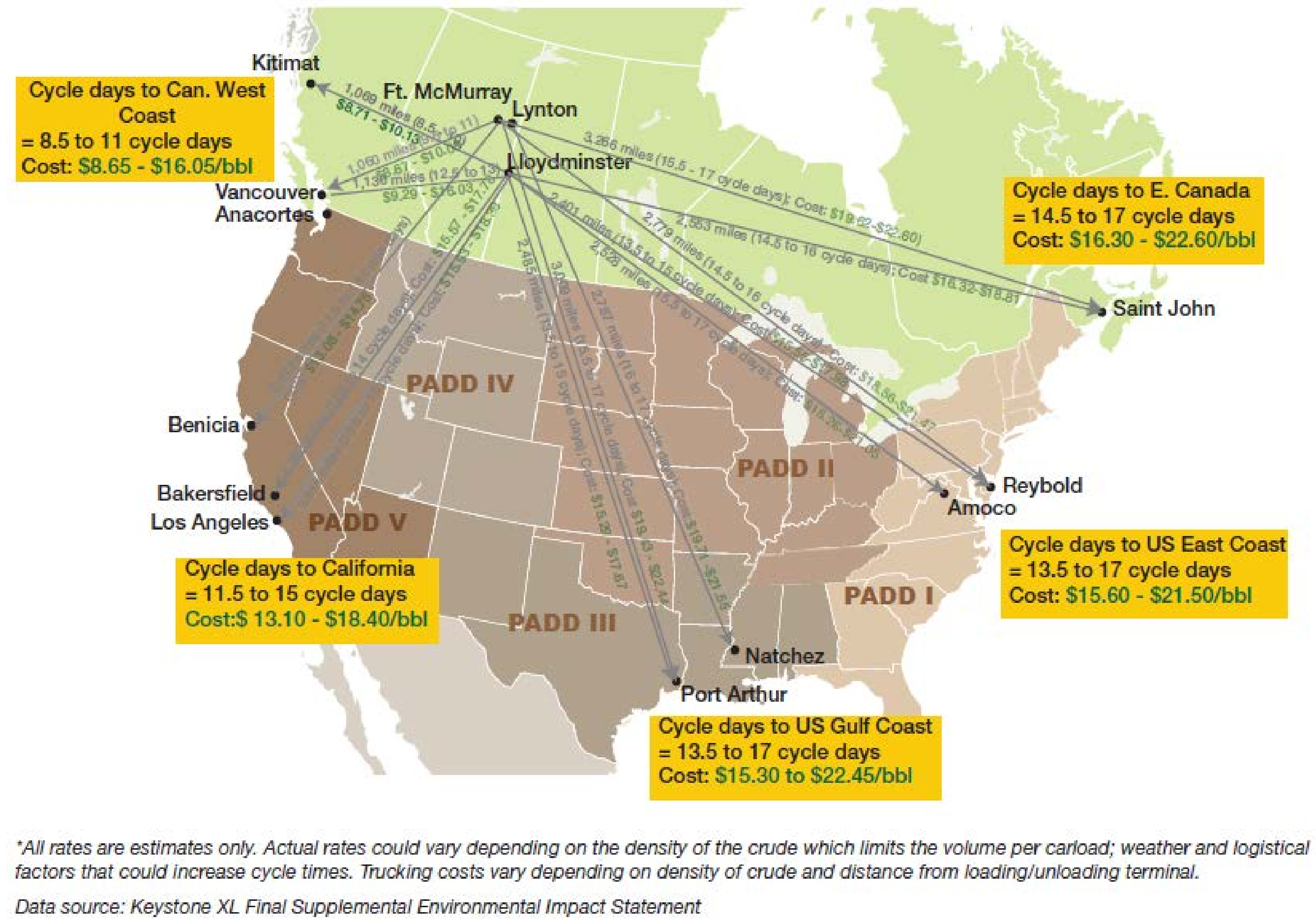
Source: (Washington State Dept. of Ecology, 2015)

Figure B-88. Increase in U.S. oil transport by rail, 2005–2014



Source: (Washington State Dept. of Ecology, 2015)

Figure B-19. Primary route of rail transport of crude oil in Washington State.



Source: (Canadian Association of Petroleum Producers, 2014)

Figure B-20. Cycle times and estimated costs for rail transportation in Canada and United States.

B.2.5.3 Vessels

Although there is refined petroleum transported on the Great Lakes—over 19 million metric tonnes in 2011—no crude oil is transported on the Great Lakes at the current time. In September 2014, the first tankers transporting crude oil for export were seen on the St. Lawrence River. These oil sands crude oils are shipped by rail from Alberta to Sorel-Tracy, Quebec and stored near the port. As the production of domestic crude oil grows, there has been an overall increase in crude oil transportation in the larger Great Lakes basin waterway system, which includes inland waterways, rivers, and canals connected to the Great Lakes. Most concerns over waterborne transportation of crude oil on the Great Lakes relate to the risk of spills from vessels. In addition, oil from oil sands is denser than traditional oil and tends to sink in water rather than float on the surface, increasing the difficulty of an effective response operation for a heavy oil spill in an emergency situation.

In anticipation of tremendous growth in the production and need for transportation of OSPs, and due to uncertainties in development of new pipelines, oil transport companies are exploring the option of increased shipping of OSPs via barges through North American waterway networks, specifically the Mississippi River for U.S. PADD II and III markets. The option of using barges in North American waterways will likely be a viable alternative on the Pacific Coast (e.g., Puget Sound) and the Great Lakes region, where waterway

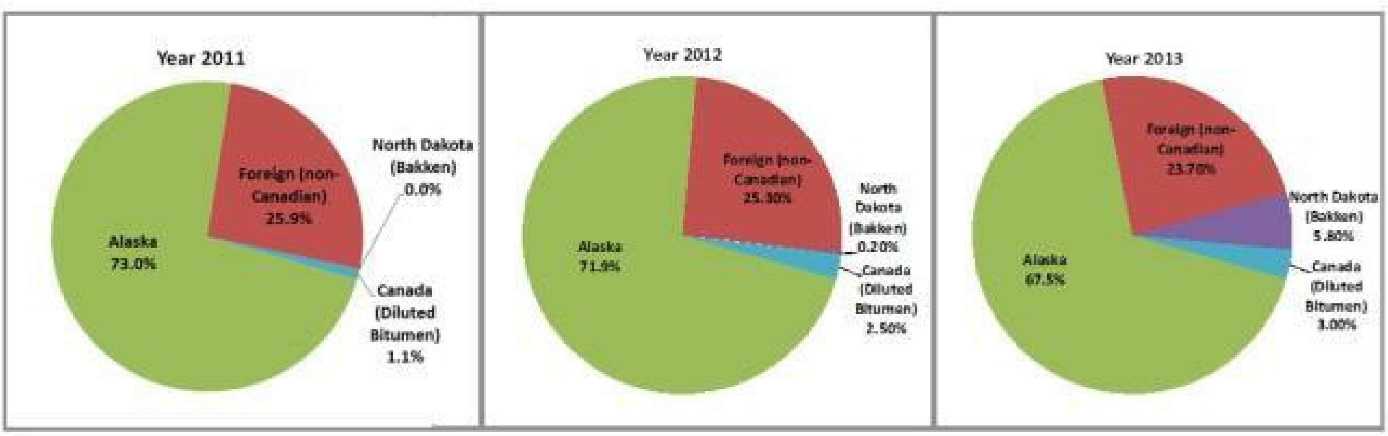
distances between crude terminal and refineries are relatively short. There are currently shipments of heavy and extra heavy crude oil products via barges from terminals in British Columbia to Puget Sound refineries in Anacortes and Tacoma.

According to the U.S. Army Corps of Engineers waterborne commerce data for the United States, crude oil is not currently being transported on the U.S. side of the Great Lakes. On the Canadian side, over 19 million metric tons of refined petroleum products were transported on the Great Lakes and through the St. Lawrence River Seaway in 2011. However, no crude oil was transported from Canadian Great Lakes ports. Larger ships traversing the Great Lakes and St. Lawrence River may carry hundreds of thousands of gallons of other refined petroleum products, distillates, and heavy fuel oil. As the production of North American crude oil continues to grow, crude oil transportation in the larger Great Lakes basin waterway system via pipeline and rail continues to increase.

A crude oil spill from a vessel could be catastrophic for the Great Lakes. The Great Lakes waters are pristine in many parts of the system, providing habitat for hundreds of species of fish and wildlife.

Barge and tanker shipment of crude and petroleum products within North America and to Asia and other consumer markets is expected to grow dramatically (International Energy Agency, 2012). It is anticipated that tanker traffic will show the greatest growth in Puget Sound, the Gulf of Mexico, and Maine, if the proposed Enbridge Gateway (West Cost), TransCanada's Keystone XL (Gulf Coast) and Kinder Morgan Trans Mountain Expansion of Portland-Montreal's Bitumen Expansion (East Coast) are approved.

In Washington State, there has been a profound change in marine transportation of crude oil from 2011 to 2013 as shown in Figure B-921 Alaska and Non-Canadian sources of crude oil have decreased from a total of 98.9 percent of crude oil transported by tank vessel in Washington State to 91.2%. The corresponding increase was in Canadian Dilbit and North Dakota Bakken crude oil (1.1 to 8.8 percent).



Source: (Washington State Dept. of Ecology, 2015)

Figure B-91. Change in origin of crude oil transported by tank vessel in Washington waters.

In a 2013 Bloomburg Business news article, Dan Murtaugh states, *"The dock probably loads 40,000 barrels of heavy Canadian crude a day onto barges that travel down the Mississippi River to Marathon's 460,000-barrel-a-day Garyville refinery in Louisiana."* (Murtaugh, 2013).

The Great Lakes Commission discusses the transportation of oil sands by vessel: (Great Lakes Commission, 2015c)

> *"The surge in Alberta oil sands has increased the total quantity of oil transported to refineries in the United States by 53 percent between 2011 and 2012. Although crude oil is not currently transported on the Great Lakes, it has been moved by barge to mid-western refineries via such inland waterways as the Mississippi, Ohio and Hudson rivers. In places such as Hennepin, Ill., and Albany, N.Y., barges are used to transport small quantities of crude oil as an alternative to rail transport. Given the known advantages of the water transportation mode (studies show that ships and barges pose fewer risks in transporting hazardous liquids than trains and trucks, and have economic advantages over other modes of transport), and the proximity of several oil refineries to major Great Lakes ports, the Great Lakes-St. Lawrence Seaway predictably deep-draft navigation system has been receiving increased consideration as a potential routing alternative."*

With the increased production of crude oil in Canada and the United States, the traditional overland modes of transportation are challenged to meet demand. The pipeline network cannot expand as quickly as needed, and the rail network is also beginning to approach capacity. In order to move crude oil to the Great Lakes and eastern refineries faster, a project was recently proposed to build a loading dock on Lake Superior, near Superior, Wisconsin, i.e., the Calumet Specialty Products-Elkhorn Industries project. Figure B-102 shows oil transportation projects on the Great Lakes.In December 2013, the Wisconsin Department of Natural Resources dismissed the application for the project due to of a lack of information. Another permit application was filed in August 2014, but did not include any information about a potential crude oil transportation project.

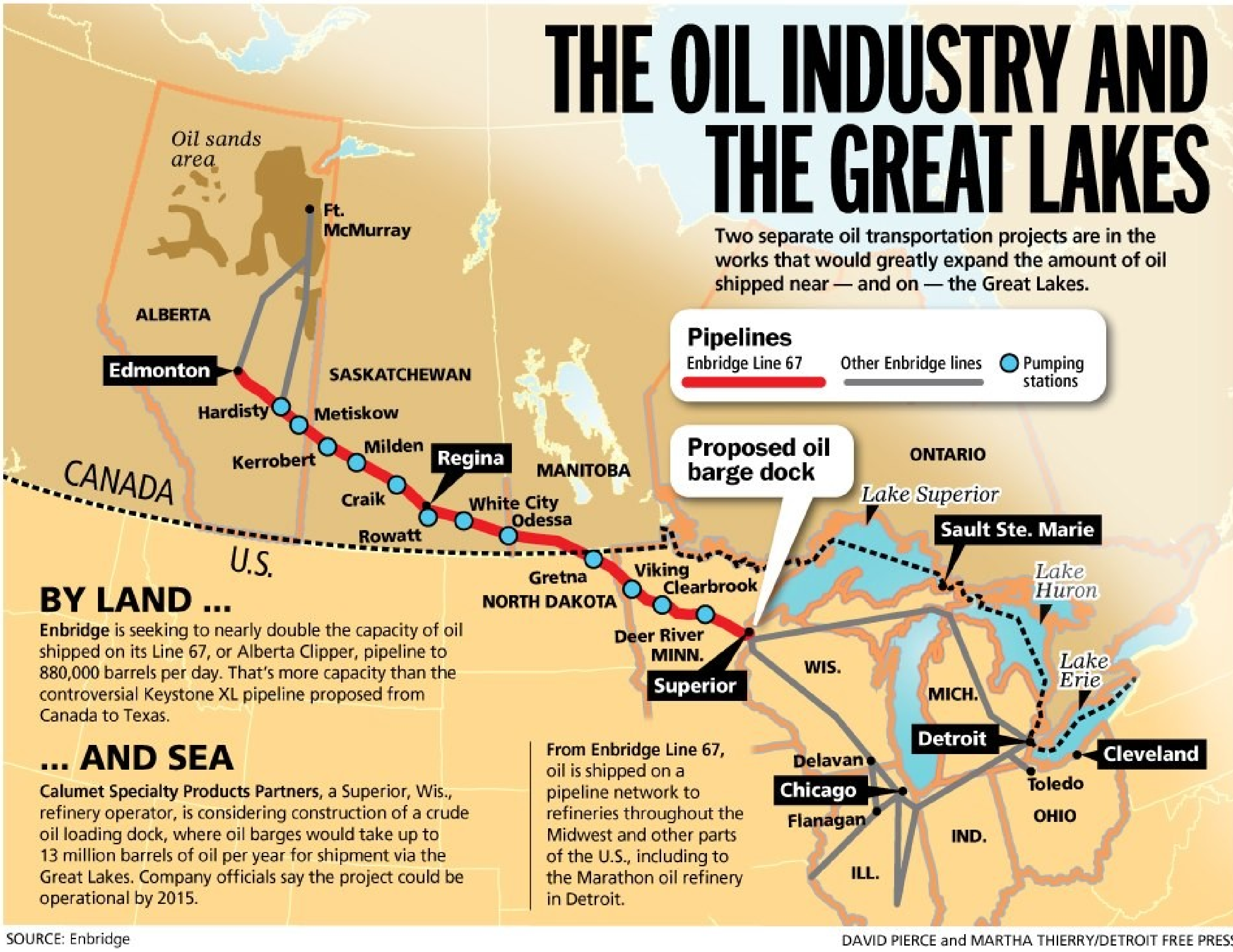


Figure B-102. Oil transportation projects on the Great Lakes.

B.2.5.4 Terminals

In the United States, downstream rail terminals are adapting to handle shipments of oil sands crude. Terminals designed to unload oil sands crude are currently concentrated in the Gulf Coast region, where the biggest concentration of heavy oil refining capacity is located.

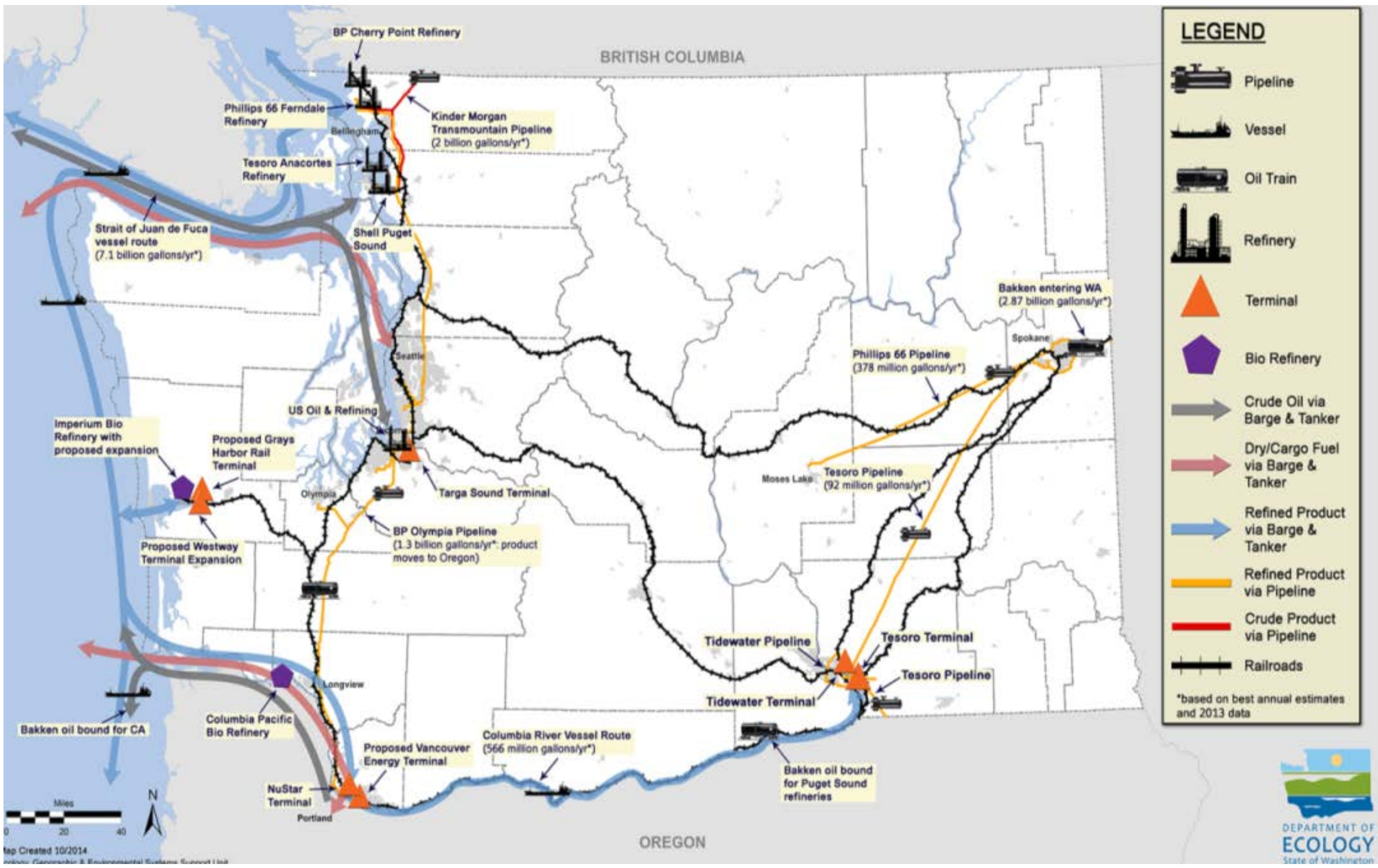
The Gulf Coast terminals currently have approximately one million bpd of unloading capacity, set to grow to over two million bbl/d in 2016. Some of this capacity is at refineries such as those operated by Valero in Port Arthur, Texas, and St. Charles, Louisiana. Valero has ordered 1,600 insulated and coiled tank cars specifically for hauling oil sands crude to its refineries.

The Gulf Coast also has significant midstream capacity on the Mississippi River, where crude oil, including oil sands crude, is unloaded from trains and pumped from storage tanks into local pipelines or loaded onto barges that deliver to coastal refineries via the Intracoastal Waterway.

In the Great Lakes basin, there are three major operating terminals, [Woodhaven (MI), Toledo (OH) and Montréal (QC)] and one under construction [Chicago (IL)]. Three of these terminals are (or will be) adapted

for "*light tight*" oil: Chicago, Woodhaven and Montréal. The one in Toledo is adapted for both "*light tight*" oil and bitumen from oil sands. The Woodhaven and Toledo terminals, and eventually the Chicago terminal, are unloading midstream terminals. The Montréal terminal and the St-Romuald terminal (near Quebec City, just outside the limits of the basin) are both unloading, downstream terminals.

Figure B-113 depicts the movement of various types of crude oil into the state of Washington, the routes and transportation modes within the state, the location of the terminals and refineries receiving the crude oil and the current export out of the state of Washington to various markets for refined products.



Source: Washington State Department of Ecology, 2015)

Figure B-113. Oil movement in and out of Washington State.

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APPENDIX C. DILBIT SPILL RESPONSE

C.1 Dilbit Spill Cases

The following are summaries of significant Dilbit spills.

2007, Burnaby, British Columbia, Kinder Morgan: On July 24, 2007, a spill resulted from an excavator bucket striking the Westridge Transfer Line in Burnaby, British Columbia, during excavation for a new storm sewer line. Approximately 58,800 gallons of synthetic crude oil flowed from the ruptured line into Burnaby's storm sewer systems until it reached the Burrard Inlet. Cleanup took place over a period of months and cost roughly $15 million.

2010, Enbridge Michigan Pipeline Spill: The largest Dilbit spill, and one of the largest inland oil spills in U.S. history, occurred on Enbridge's Line 6B pipeline on July 25, 2010 in Marshall, Michigan. Line 6B is a 293-mile section of the Lakehead system, which originates in Edmonton, Alberta. The rupture was not discovered for more than 17 hours.

Two types of Dilbit oil were spilled during the Enbridge pipeline spill into the Kalamazoo River system: Cold Lake and McKay River Heavy. Enbridge did not initially report that the pipeline was carrying Dilbit. **Disclosure of this information is not required, and thus it took more than a week for federal and local officials to discover they were dealing with a Dilbit spill.** The release, estimated at 843,000 gallons, entered Talmadge Creek and flowed into the Kalamazoo River, a Lake Michigan tributary. Heavy rains caused the river to overtop existing dams and carry oil 35 miles downstream on the Kalamazoo River.

The Dilbit that spilled in Marshall was composed of 70 percent bitumen and 30 percent diluents. Although the Dilbit initially floated on water, it soon began separating into its different components. Most of the diluents evaporated into the atmosphere, leaving behind the heavy bitumen, which sank under water. According to documents released by the National Transportation Safety Board, it took nine days for most of the diluents to evaporate or dissolve into the water. There are no municipal drinking water intake sites but there were several industrial water intake sites along the Kalamazoo River. A major concern during the spill incident concerned contaminated ground water. Municipal officials noted that drinking water wells were located as close as 200 feet to the contaminated river. EPA reported that the Marshall and Battle Creek municipal water systems have not been affected by the oil spill and no well contamination has been detected.

The Dilbit initially floated on the fresh water. However, after mixing with sediments and the evaporation of the light hydrocarbons from the diluents, the density of some fractions of the residual oil increased, causing the oil to sink. As a result, there were times during the response when the Dilbit was simultaneously floating, submerged in the water column, and on the bottom of the river. Beyond the characteristics of the oil, the water temperature, the presence of sediments, and the velocity of the river affected oil recovery.

An Associated Press article stated that Enbridge has estimated cleanup costs to be about $1.2 billion (Associated Press, 2014). Cleanup of the 2010 spill was not completed until 2014.

2010, Enbridge Illinois Pipeline Spill: Two months after the Kalamazoo River spill in Michigan, another spill occurred on the Enbridge Lakehead System, on Line 6A in Romeoville, Illinois. On September 9, 2010, a rupture resulted in a release of about 255,990 gallons of Dilbit. As with the Michigan spill, the

initially available information was not specific about the nature of the product in the pipeline; i.e., press releases describing the pipeline did not explicitly state that it carried Dilbit. The response was completed on October 28, 2010 with an estimated cleanup cost of $45 million.

2011, Ludden, North Dakota, TransCanada: A failure at a North Dakota pump station resulted in a spill of about 21,000 gallons of Dilbit on May 7, 2011, causing the entire pipeline system to shut down for nearly one week. Reports from the North Dakota Public Service Commission assert that the spill was not due to the pipeline itself, but rather resulted from a failed fitting for a valve on the discharge piping for the line. All but approximately 210 gallons of the spilled oil were reported to have been contained within the boundaries of the pumping station.

2013, Mayflower, Arkansas, ExxonMobil Pegasus: The 2013 Mayflower oil spill occurred on March 29, 2013, when an ExxonMobil pipeline carrying Canadian Wabasca heavy crude from the Athabasca oil sands ruptured in Mayflower, Arkansas, about 25 miles northwest of Little Rock. There was confusion over the type of oil being carried, as it was initially reported to be a heavy Canadian crude oil, but later (April 10) it was clarified as being Wabasca Heavy, a heavy sour Dilbit product. Estimates of the amount of product released have varied from 84,000 to 210,000 gallons. Approximately 504,000 gallons of oil mixed with water have been recovered. Twenty-two homes were evacuated. The United States Environmental Protection Agency (EPA) classified the leak as a major spill. A 2013 Los Angeles Times article stated that ExxonMobil spent more than $70 million so far dealing with the spill (Banerjee, 2013).

C.2 Dilbit Behavior

Bitumen is too thick to be pumped from the ground or through pipelines. Instead, the heavy tar-like substance must be mined or extracted by injecting steam into the ground. The extracted bitumen has the consistency of peanut butter and requires extra processing before it can be delivered to a refinery.

There are two ways to process the bitumen. Some oil sands producers use on-site upgrading facilities to turn the bitumen into synthetic crude, which is similar to conventional crude oil. Other producers dilute the bitumen using either conventional light crude or a cocktail of natural gas liquids. The resulting Dilbit has the consistency of conventional crude and can be pumped through pipelines.

Dilbit's potential for sinking after weathering, i.e., losing its light fractions to evaporation, was the impetus for a series of tank test studies on the behavior of Dilbit when spilled into freshwater or brackish marine waters. As stated in the Washington State Marine & Rail Oil Transportation Study, Mesoscale weathering experiments conducted in Gainford, Alberta showed that Cold Lake and Access Western Blend Dilbit blends exhibited properties typical of a heavy, "conventional" crude oil as they weathered but in no instance was any oil observed to have sunk after ten days of weathering on 20 parts per thousand brackish water under varied physical conditions (Washington State Dept. of Ecology, 2015). The physical properties of weathering oil measured during those tests showed that Dilbit spilled into fresh, brackish, or saltwater will stay on the water surface for days unless another mechanism mixes it into the water column, as would be the case for most Group III and IV oils. Only after extensive weathering, or mixing with suspended particulate material, may some portion of weathered Dilbit sink or become submerged.

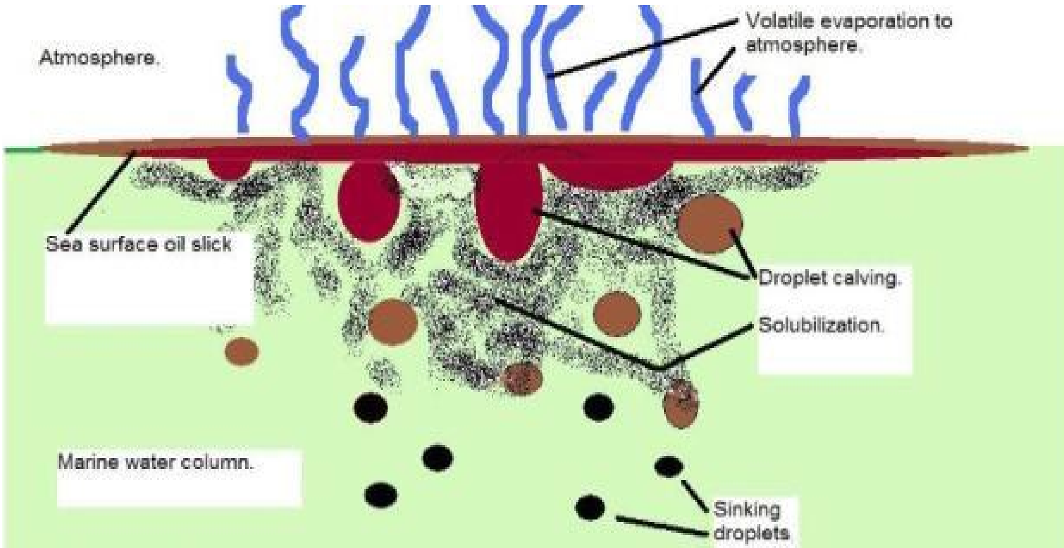
In another series of studies conducted by the Government of Canada on two Dilbit products that represented the highest volume transported by pipeline in Canada during 2012–2013—Access Western Blend and Cold Lake Blend, the researchers concluded:

- Like conventional crude oil, both Dilbit products floated on saltwater (free of sediment), even after evaporation and exposure to light and mixing with water.
- When fine sediments were suspended in the saltwater, high-energy wave action mixed the sediments with the Dilbit, causing the mixture to sink or be dispersed as floating tar balls.
- Under conditions simulating breaking waves, where chemical dispersants have proven effective with conventional crude oils, a commercial chemical dispersant (Corexit 9500) had quite limited effectiveness in dispersing Dilbit.
- Application of fine sediments to floating Dilbit was not effective in helping to disperse the products.
- The two Dilbit products display some of the same behaviors as conventional petroleum products (i.e. fuel oils and conventional crude oils), but also some key differences, notably for the rate and extent of evaporation.

As Dr. Fingas further explains: (Fingas, 2014)

> *"Oil spilled on water undergoes a series of changes in physical and chemical properties which in combination are termed 'weathering'. Weathering processes occur at very different rates, but begin immediately after oil is spilled into the environment. Weathering rates are not consistent throughout the duration of an oil spill and are usually highest immediately after the spill. Both weathering processes and the rates at which they occur depend more on the type of oil than on environmental conditions. Most weathering processes are highly temperature dependent, however, and will often slow to insignificant rates as temperatures approach zero degrees. The processes included in weathering are evaporation, emulsification, natural dispersion, dissolution, photo oxidation, sedimentation, adhesion to materials, interaction with mineral fines, biodegradation, and the formation of tar balls. These processes are listed in order of importance in terms of their effect on the percentage of total mass balance, i.e., the greatest loss from the slick in terms of percentage and what is known about the process. Evaporation is particularly important for Dilbits. Dilbits evaporate leaving the much denser and much more viscous bitumen behind. There exists laboratory data and small test tank data on the weathering of Dilbits. This data was compared and the equivalent viscosity and density were compared for % weathered and time and the scale then approximated over days rather than % weathered. This was done to provide a practical base for spill countermeasures. An issue that is important to health and safety is that of flammability. The Dilbits when released, can be flammable, especially those enhanced with C4 or C5."*

Evaporative studies of Dilbit blends (e.g., Cold Lake) have shown that the first few hours of exposure to air results in the rapid loss of portions of the diluent with resulting increases in density and viscosity. Evaporative loss rates are affected by air temperature, oil surface area and thickness on the water surface, wind, and sea state conditions. But, the studies also showed that because of the minimal light-end content of the Dilbit, the final evaporative loss of Dilbit was similar to Alaskan North Slope (ANS) crude. The Dilbit exhibited an eight percent volume loss through evaporation. This loss corresponds to an eight percent increase in density. In freshwater, this evaporation may cause the oil to become heavier than water. However, it is unlikely to cause submergence in marine salt waters or even most brackish estuarine waters.



Source: (Washington State Dept. of Ecology, 2015); Thibodeaux et al. 2011

Figure C-1. Evaporation/dissolution from a sea surface slick.

In a 2012 Inside Climate News article, Lisa Song stated, “On July 16, 2010, just nine days before the Marshall accident, the EPA warned that the proprietary nature of the diluents found in Dilbit could complicate cleanup efforts. The EPA was commenting on the State Department’s Draft Environmental Impact Statement (EIS) of the Keystone XL pipeline.” (Song, 2012).

The December 2014 Congressional Research Service report made the observation in the aftermath of a 2010 pipeline spill are consistent with the assertion that Dilbit may pose different hazards, and possibly different risks, than other forms of crude oil (Frittelli, et al., 2014). On July 26, 2010, a pipeline owned by Enbridge Inc. released approximately 850,000 gallons of Dilbit into Talmadge Creek, a waterway that flows into the Kalamazoo River in Michigan. Three years after the spill, response activities continued because, according to EPA, the oil sands crude “*will not appreciably biodegrade*.”

The Dilbit sank to the river bottom, where it mixed with sediment, and EPA ordered Enbridge to dredge the river to remove the oiled sediment. As a result of this order, Enbridge estimated in September 2013 its response costs would be approximately $1.2 billion, which is substantially higher than the average cost of cleaning up a similar amount of conventional oil.

> *"First, we note that in order for the bitumen to be transported by the pipeline, it will be either 'diluted with cutter stock (the specific composition of which is proprietary information to each shipper) or an upgrading technology is applied to convert the bitumen to synthetic crude oil,'" the EPA wrote. "…Without more information on the chemical characteristics of the diluent or the synthetic crude, it is difficult to determine the fate and transport of any spilled oil in the aquatic environment.*
>
> *"For example, the chemical nature of diluent may have significant implications for response as it may negatively impact the efficacy of traditional floating oil spill response equipment or response strategies. In addition, the Draft EIS addresses oil in general and as explained earlier, it may not be appropriate to assume this bitumen crude/synthetic crude shares the same characteristics as other oils."*

Dr. Fingas summarizes his paper as follows: (Fingas, 2014)

> *"Diluted bitumens are Alberta oil sands bitumen diluted either by condensate, C4/C5 enhanced condensate (Dilbit) or synthetic crude oil (Synbit). Once spilled the Dilbits return to the properties of the starting bitumen as the volatile components evaporate. A spilled Synbit does not return to the properties of the starting bitumen, but rather weathers to a heavier oil, moderating properties between a weathered synthetic crude and a bitumen."*

The figure below shows the typical viscosity change for each type of Dilbit.

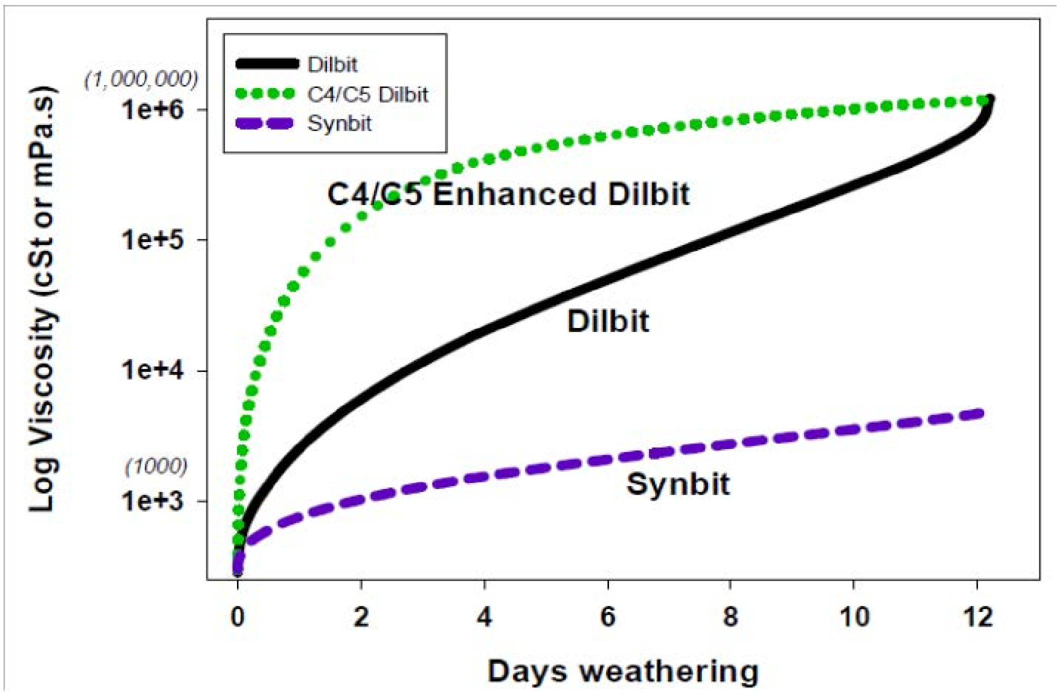


Figure C-2. Viscosity change for the three types of diluted bitumen.

> *"The above figure shows the **viscosity changes** for the three types of diluted bitumens. These are calculated at 15◦ C."*

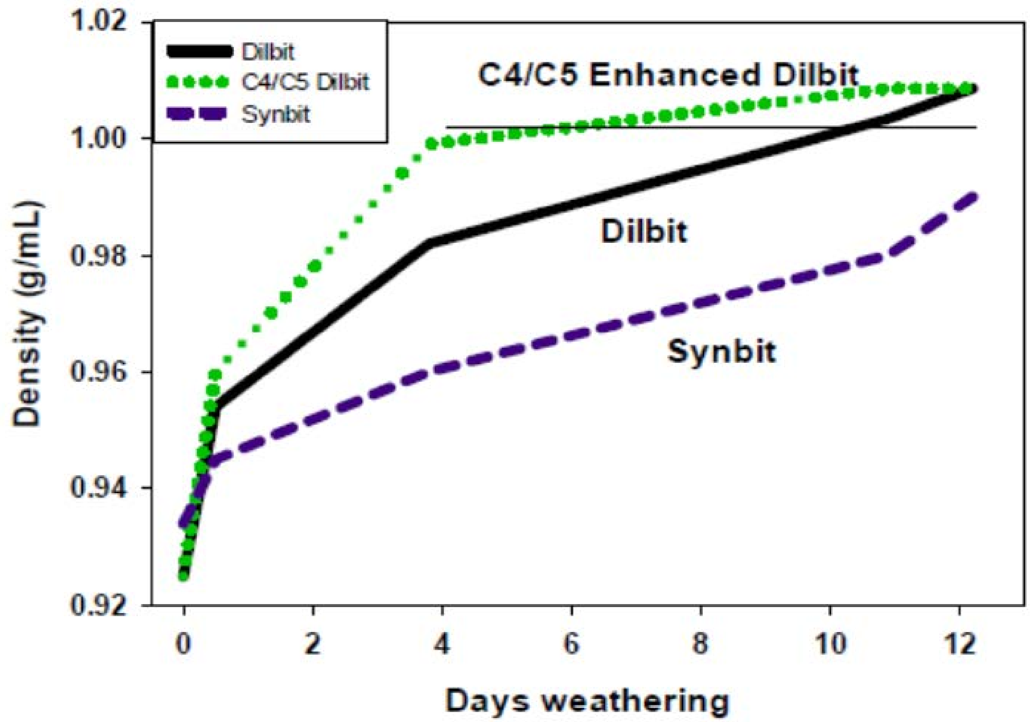


Figure C-3. Density change for the three types of diluted bitumen.

"The figure above shows the ***density changes*** *of the three types of diluted bitumens. These are calculated at 15◦C."*

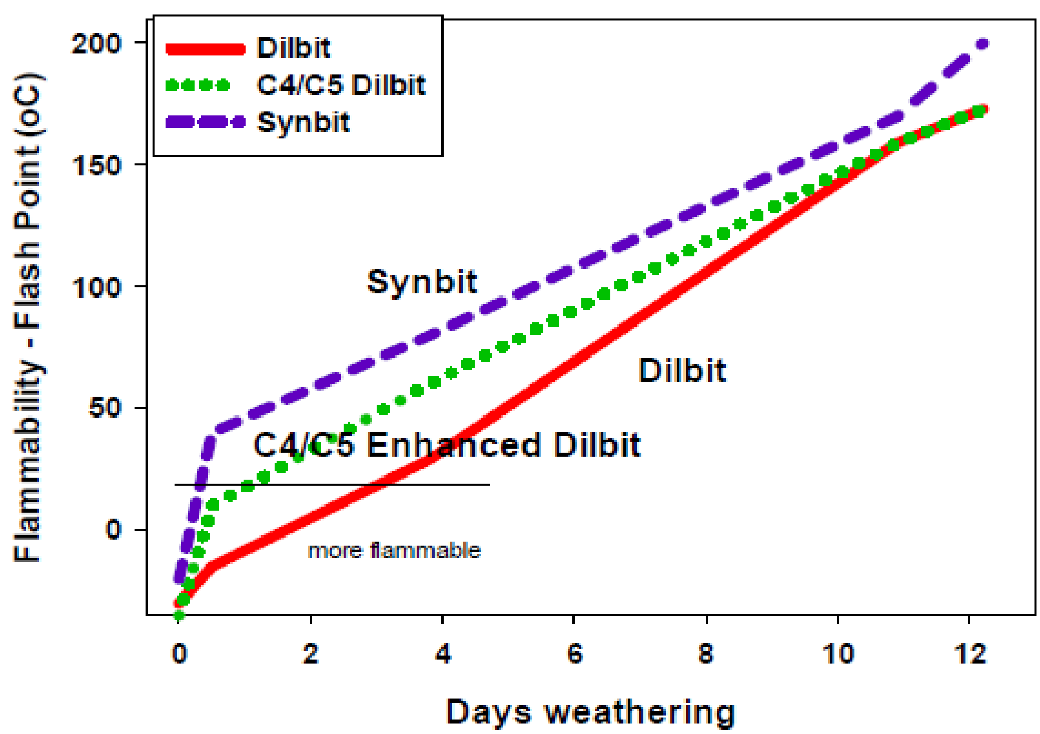


Figure C-4. Flammability (flash point) change for the three types of diluted bitumen.

> *"The **flammability (flash point) changes** for the three types of diluted bitumens as these products weather. The above figure shows that C4/C5 enhanced Dilbit is the most flammable product but for only about one day of exposure. Regular Dilbit is flammable for about 2 days and Synbit for about half a day after the spill."*

> *"It was found that when initially spilled all three products can form entrained water mixtures in turbulent waters. After weathering, Dilbits are too viscous to form such products. Entrained water types would break down naturally after a time once the turbulence is removed. In inland waters emulsification is rare."*

> *"Spill countermeasures for spilled Dilbits and Synbits can proceed with either skimming and/or in-situ burning. Initially when spilled Dilbits require a regular skimmer and later a heavy oil skimmer. Synbits are similar, however the regular skimmers might be used throughout the cleanup cycle. Only after extensive weathering are heavy oil skimmers required for Synbit spills. On shorelines or solid surfaces, EC 9580 (EC 9580 is an oil herding agent) works until the product is weathered more than 5 days. High pressure washing is effective until the products weather longer than about a week. Oiled surfaces may be a challenge to clean up."*

A contentious topic that emerges out of the current discussion concerns oil characteristics and the implications for transportation infrastructure, while some research indicates that raw oil sands products (OSPs) have higher sulphur content than medium and light crude oils and can contribute to corrosivity, other research suggests that OSPs in their transported state are not more corrosive than standard crude oil.

C.3 Equipment

Michel, Ploen, and Elliot opined on various detection systems for detecting oil on the bottom (Michel, Ploen, & Elliot, 2014).

Acoustic Systems

- Provide lots of good capabilities: no water clarity limits, geo-referenced, good areal coverage rates, available technology.
- Have lots of limitations: detection limits for oil thickness, patch size; substrate effects; shallow water depth; post-processing time; needs validation.
- There is little experience in response community with this system.
- Provides promising improvements in real-time data processing and calibration.

Vessel-Submerged Oil Recovery Systems (V-SORS)

- Advantages:
  - Can detect both pooled and mobile oil moving above the bottom.
  - Efficient; could be towed at up to five knots.
  - Can vary trawl length to refine spatial extent.
  - Has good positioning capability with onboard GPS and navigation system.
  - Can be used in traffic lanes.
- Disadvantages:

- Cannot determine where along the trawl the oil occurred.
- Difficult to calibrate effectiveness of oil recovery.
- Certain vessel requirements.
- Time and labor intensive.
- Needs white snare.

ROV Video/Photography

- Water visibility/weather limits.
- Systems with good GPS tracking of ROV.
- Not much experience in response community on capabilities.
- Need rapid post-processing to produce useful products (geo-referenced oil maps).

Airborne Laser Fluorescence

- Uses ultraviolet lasers to excite aromatic compounds in oils and detect resulting fluorescent emission.
- Only effective for water depths of one to two meters.
- Effectiveness drops off with water depth and turbidity.

C.4 Techniques and Tactics

Initial stages of an OSP spill would consist of:

- Similar to a crude oil spill with response resources focused on surface response methodologies and public and responder safety.
- Identify methods and equipment that might be effective for recovering oil on the surface or bound to the sediment.
- Establish an air monitoring and safety program to protect the public and establish the safety protocol for the responders and obtain the needed air monitoring and respiratory protection equipment.
- Identify resources at risk and assess the extent of the spill, both surface and subsurface.
- Identify the characteristics of the OSP spilled beyond the MSDS to assist in establishing safety protocols and determining cleanup strategies.
- Knowledge of the specific diluent and the characteristics of the OSP would be central to any response actions to be taken.
- Provision of accurate information to the public about an OSP spill including information on any known toxicity issues and the closure of any fisheries or affected water intakes.
- Continued outreach to the public must occur throughout the cleanup process to keep the public informed about the progress of the response and any restoration efforts.

The Counterspil Research paper states: (Counterspil Research, 2011)

> *"Specific gravity and subsequent movement of viscous oils would not only be affected by emulsification and sedimentation, but also by tidal and other currents, wind generated waves, low temperatures, salinity anomalies, and other factors. Should the viscosity of a heavy oil become so high that the pour point is exceeded, i.e., the oil ceases to flow, and then the spill might not be amenable to conventional methods applied to releases which remain on the water surface. This oil spill behavior results in well-recognized challenges*

> *to responders that researchers have investigated for some time. The potential submergence or at least over-washing of viscous, spilled oil requires specific control strategies. Sinking can occur not only with oils with a specific gravity greater than 1 but also with oils with specific gravities within a few percent less than 1 (i.e., less dense than water) (Usher, 2006)."*

GRPs are developed through workshops and field work involving federal, state, and local oil spill emergency response experts, resource trustees, representatives from tribes, local governments, industry, ports, environmental organizations, pilots, communities and response contractors. Workshop participants identify resources, develop response strategies, and help prioritize the strategies based on potential oil spill origin points. It is important to involve local governments and local communities in the GRP development process.

Existing and potential new sites are visited in the field to gather data about the location. Many factors recorded during field work must be considered when developing response strategies, including: tides and tidal currents river speed and conditions, shoreline and resource sensitivity to oil, cultural resources, seasonal weather changes, equipment availability, site access, and more. Modifications are made as needed, and further details can be added to hone the strategy. Experiences from actual spills and exercises provide an efficacy test of the final strategies.

GRP protection strategies should be refined and enhanced as needed once a coordinated response has been established. Additional sensitive areas should be identified and additional response strategies beyond those listed in the GRP should be developed, based on incident specific assessments and input from resource trustees and persons with local knowledge.

The Washington State study determined the following: (Washington State Dept. of Ecology, 2015)

- *GRPs have not been developed for most of the rail corridors through which crude by rail trains are transiting or will transit in future. There are also gaps in GRPs for marine areas. Capacity does not exist in the state to update and field test GRPs on a regular basis.*
- *A preliminary analysis conducted by the Northwest Area Committee (NWAC) Oil by Rail Task Force GRP Gap Analysis Work Group (2014) indicated that GRPs have not been developed for most rail corridors although there is some overlap in marine areas where trains travel along the Puget Sound (South Puget Sound, Central Puget Sound, North Central Puget Sound, and Columbia River) and there is some overlap with Pipeline companies who have developed company specific response strategies.*
- *In addition to gaps in plans for certain inland regions, there are also gaps in marine areas. While the goal is to maintain and update GRPs every five years, historically, Ecology has not been able to do this on a regular basis. There have not been sufficient resources to make progress in testing GRP strategies through response equipment deployment.*

Booth and Macon make recommendations of a series of logical first steps that local response communities can take to increase their preparedness, training, and outreach in preparation for spills of Canadian OSPs. These recommendations are as follows: (Booth & Macon, 2014a)

- Identify natural collection areas where sunken oil would be most likely to collect or pool. The cost-effectiveness of this activity will depend on the existing information and datasets available in each area. Area Committees can review collection points already identified within their Area Contingency Plans

particularly GRPs. Area Committees should consider focusing their effort on identifying natural deposition areas near OSP production and storage facilities and along transportation routes. Identifying this information in advance can assist with the development of OSP response strategies designed for submerged or sunken oil, which may not be addressed in the current Area Contingency Plan or may differ from response measures outlined in existing Geographic Response Plans.

- Update Contingency Plans to account for OSPs. If an OSP is present in the local area, Area and Regional Contingency Plans should be updated to account for these products (CSE, 2012). In 2014, the NW Area Committee added a section to the NWACP titled 'Submerged or Sinking Oils – Policy and Operational Tactics,' which addresses the presence, response considerations, and best practices for sinking oils (including OSPs*)* within their area of responsibility (Northwest Area Committee, 2014). The recommendation to update Contingency Plans so that they adequately address OSPs was also voiced by the Alliance for the Great Lakes (Alliance for the Great Lakes, 2013) When conducting Contingency Plan updates, planners should keep in mind that, although OSPs may behave like highly persistent Group V oils (oils that have a specific gravity greater than 1.0) once weathered in the environment, they are often classified as (and subject to the regulations for) Group IV oils (oils that have a specific gravity greater than 0.95 and less than 1.0) due to their physical characteristics as a blended product (NOAA, 2013). It is critical that planners acknowledge and plan for this reality when updating the Contingency Plans to account for the presence of OSPs. Information about the locations where OSPs may be encountered and the areas of deposition where sunken oil could collect or pool should also be included in these Contingency Plan updates.
- Conduct local area exercises that address oil sands spill scenarios. Once the Contingency Plans have been updated, the information outlined in the plan should be assessed by conducting an exercise based on an OSP spill scenario. Federal and State exercise designers should make every effort to include industry partners and plan holders that produce, store, or transport OSPs in their PREP exercises.

Booth & Macon conclude that the increased development and transportation of OSPs presents new challenges for the oil spill response community. Enhancements to the ability to respond to these new challenges can be accomplished through preparedness activities to ensure contingency plans adequately address this new challenge; training activities to ensure that responders have the knowledge they need to conduct an effective and timely OSP response; and outreach activities to ensure that the responders, regulators, and stakeholders are coordinated and informed and to promote awareness of the importance of accurate product characterization in reports to the National Response Center (NRC). The need for additional research to reduce the uncertainty related to the physical and chemical behavior of OSPs when spilled into the aquatic environment still exists. While local response communities may not have the resources and abilities to reduce this uncertainty; they can nevertheless conduct impactful preparedness, training, and outreach activities to better prepare themselves and their communities for this new era in oil development.

To improve contingency planning for future marine spills, additional protocols should be developed for air monitoring and surface and subsurface responses. More information on transportation of OSPs needs to be part of the planning, and OSP response actions need to be incorporated into drills so that responders have the knowledge and experience to provide timely and effective response to OSP spills.

A more thorough evaluation should be developed for locations that might be considered as higher likelihood of spills due to accidents, such as vessel collisions/allisions and train derailments, and that would also be associated with potentially high spill consequences (e.g., high population density or environmentally sensitive areas). This evaluation could be used for the purposes of evaluating the commodity flows through those locations, analyzing the probability of defined incident scenarios in those locations, and for pre-

planning of the type and amount of response resources that might be needed. This evaluation will help in determining the situations that present the greatest risk (high probability of incident and high consequences).

The knowledge of present response capabilities and adequacy and availability of response resources to meet the planning standards throughout the state of Washington for responding to oils that may have a tendency to sink or submerge in inland and marine spill situations is not sufficiently understood to make a recommendation other than that the NWAC should specifically conduct a study to review the current response resources attributed to submerged oil response in the state of Washington and develop a definitive status of specific submerged oil response tools and tactics. For inland areas, information on fast-water response tactic is also lacking."

Hazard Awareness - Canadian Tar Sands Oil (U.S. Coast Guard, 2014)

> *"Diluents, a fluid used to lower viscosity, are added to bitumen based oils (Tar Sands Oil) in large enough quantities to make the original product easier to pump and transport. A diluent frequently used in large volume is Natural Gas Condensate. Natural Gas Condensate consists of many short chain hydrocarbons, which include various alkanes, alkenes, BTEX, and longer single chain chemical variants. Natural Gas Condensate can have a proper shipping name of Petroleum Distillates, N.O.S., which is classified as a dangerous good under the IMDG Code. Some of the hazards include: flammability; easily ignited by heat, sparks or flames; vapors forming explosive mixtures with air; toxicity through various routes of exposure; and being volatile at room temperature. Once the diluent is separated from the product, the original physical properties of the bitumen return which emulate characteristics of roofing tar. In a marine or aquatic environment, and under the right conditions, this dense product could sink to the bottom of the impacted waterway making recovery efforts far more challenging and time consuming than traditional recovery techniques."*

Steps to Protect Responders (Excerpt from Gulf Strike Team Bulletin Supplement; Responder Awareness – North American Crude Oil Shipments) (U.S. Coast Guard, 2014)

> *"VOCs, including BTEX, can pose a direct hazard to the health of responders. Each type of oil presented above is acknowledged to contain these compounds, which during a response, present at a minimum an inhalation hazard to responders. One way to mitigate this hazard is to have the appropriate detection capabilities deployed to properly identify and quantify the hazard prior to impacting response personnel. Once quantified, appropriate personnel protective strategies can be implemented, such as the wearing of an air purifying respirator or self-contained breathing apparatus. Special air monitoring equipment may be required to properly identify BTEX hazards. Should a response event involve any of the above discussed oils, ensure that appropriate equipment is a part of the planning phase of a deployment to alert responders to a potential hazard."*

Another potential hazard that responders may need to be aware of regarding bitumen, bitumen blends, and syncrude is flammability. A 2015 Reuters article by Nia Williams reminded readers that two recent rail derailment and fire incidents involved synthetic crude. The article states: (Williams, 2015)

"Two recent oil-train derailments in Canada have opened a new front on the debate over safety, highlighting how even shipments of Alberta's oil sands crude can contain components just as volatile as North Dakota's Bakken.

Although Canada is best known for producing viscous bitumen that is not prone to ignite on its own, it is often blended with as much as one-third super-light oil - known as condensate - before it is shipped in rail cars, injecting the same kind of volatile gases that can explode in derailments, industry experts say.

In the case of two fiery incidents in northern Ontario in recent weeks, the oil involved was synthetic crude from the Alberta oil sands, which is upgraded from raw bitumen, making it less stable.

Both Canadian National Railway trains were heading to a Valero Energy Corp's refinery in Quebec before they came off the tracks and burst into flames.

Ever since the Lac-Megantic disaster in Quebec, where a runaway train carrying Bakken crude erupted in a fireball in 2013, killing 47 people, worries about safety have been largely centered on light crude. In particular, Bakken has been the focus since its so-called "light ends," volatile gases with higher vapor pressure and low flashpoints, occur naturally.

But light ends are also present in the condensate used to dilute raw bitumen and some heavy crude. Even though the concentration in diluted bitumen, known as Dilbit, is far less than in Bakken, the low flashpoint remains.

For Canada, the issue is not only the point at which diluted or synthetic oil sands crude might ignite, known as the flash point, but whether it would continue to burn once ignited, potentially setting off a series of blasts in adjacent tank cars.

Bakken crude is naturally rich in light ends so its flash point and fire point are roughly the same, says Andre Lemieux, secretary of the Canadian Crude Quality Testing Association (CCQTA), meaning if it ignites it will continue to burn.

However, the same is not necessarily true for crude being produced in and shipped from Alberta.

To complicate matters, there is no such thing as a typical Canadian crude. Different grades have different properties with light sweet crude streams tending to have lower flash points than undiluted heavy grades. The concentration of light ends in Dilbit vary depending on the quantity and quality of condensate added. Some shippers use semi-refined synthetic crude instead of condensate, to make a product called "Synbit".

Synthetic crude presents a different challenge because as an upgraded product its flash and fire points may be quite different from crude oil. One of the safer substances to transport by rail is raw bitumen from the oil sands, which in its undiluted state is the consistency of peanut butter and extremely difficult to ignite.

> *However, raw bitumen shipments require coiled and heated rail cars and additional infrastructure at rail loading and off-loading terminals, which not all shippers have access to.*
>
> *Industry bodies including CCQTA and Transport Canada are now studying the flammability of various types of crude, and their results may have implications for how certain kinds of oil is shipped and how emergency services deal with crude train derailments.*
>
> *Progress is likely to be slow, however. Researchers are developing new testing methods, since the existing United Nations methods for classifying dangerous goods transported by rail were originally developed for natural gas liquids like ethane and propane rather than mixed cargoes like crude oil.*
>
> *"Ultimately the specific properties of crude oil and types of crude oil will become much more important as it relates to how material is transported," the CCQTA's Lemieux said. "But it will take a while."*

First responders are typically the first to arrive when an incident occurs and results in the release of oil, fire/explosion and/or toxic fume emissions. First responders initiate immediate safety measures to protect the public. Local fire, law enforcement, rescue units and other local, county, or state emergency management officials are responsible for carrying out local, county, or state emergency response and evacuation plans.

The National Contingency Plan (NCP) indicates that state or local officials may be responsible for conducting evacuations of affected populations. These first responders also may notify the National Response Center to elevate an incident for federal involvement, at which point the coordinating framework of the NCP would be applied.

If flammability is a public safety issue with OSPs, e.g., Dilbit, then as the ERC Washington State Marine and Rail study also determined, there is a significant need for local, county, and state emergency first responders to be able to respond effectively to incidents that may occur with oil tar sands incidents that may include a fire and toxic emission event (Washington State Dept. of Ecology, 2015). This means that First Responders may need additional training, equipment, and resources to respond to an OSP spill incident that occurs with associated fire and toxic fume emissions. The ERC Washington State Marine and Rail Study recommended: needing more extensive preparedness and response coordination between first responders and the owner/operators/Responsible Parties of rail, marine, and pipeline as to resource availability that first responders might need access to particularly concerning fire suppression and toxic emissions; closing knowledge gaps of existing response plans and strategies by increasing communications and information sharing with first responders; assisting in ensuring that first responders are adequately trained for the products being transported or handled in their jurisdictions, especially if there is a need for Hazardous Material Response Teams; exercising with first responders in order to ensure that the Responsible Party, Federal, State, and Local agencies understand where each jurisdiction fits within the Unified Command structure.

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APPENDIX D. REFINERIES FOR OIL SANDS PRODUCTS

The following tables depict the locations of the refineries that are refining Oil Sands Products (Oil Change International, 2012).

Table D-1. U.S. refineries located in PADD 1 (East Coast) refining oil tar sands (2012 Data).

Refinery Name	Company Name	State	Estimated Tar Sands Usage (bbls/day)	Estimated Tar Sands % of Refining Capacity
Bayway	Phillips 66	NJ	4,000	2%
Delaware City	PBF Energy	DE	3,000	2%
Paulsboro	PBF Energy	NJ	2,000	2%
Paulsboro	Axeon Specialty Products	NJ	<1,000	--
Warren	United Refining	PA	9,000	14%

Table D-2. U.S. Refineries located in PADD 2 (Mid-West) refining oil tar sands (2012 Data).

Refinery Name	Company Name	State	Estimated Tar Sands Usage (bbls/day)	Estimated Tar Sands % of Refining Capacity
Canton	Marathon	OH	11,000	15%
Catlettsburg	Marathon	KY	30,000	16%
Coffeyville	CVR Energy	KS	16,000	16%
Detroit	Marathon	MI	44,000	46%
El Dorado	Holly Frontier	KS	26,000	21%
Joliet	Exxon Mobil	IL	164,000	76%
Lemont	Citgo	IL	78,000	51%
Lima	Husky Energy	OH	57,000	41%
McPherson	Cenex Harvest	KS	14,000	19%
Pine Bend	Flint Hills	MN	207,000	77%
Ponca City	Phillips 66	OK	12,000	7%
Robinson	Marathon	IL	23,000	12%
St. Paul	Northern Tier Energy	MN	34,000	44%
Superior	Calumet Specialty Products	WI	18,000	50%
Toledo	PBF Energy	OH	80,000	55%
Toledo	BP-Husky Refining	OH	28,000	24%
Tulsa	Holly Frontier	OK	2,000	1%
Whiting	BP plc	IN	159,000	43%
Wood River	WRB Refining	IL	159,000	49%

Table D-3. U.S. Refineries located in PADD 3 (Gulf Coast) refining oil tar sands (2012 Data).

Refinery Name	Company Name	State	Estimated Tar Sands Usage (bbls/day)	Estimated Tar Sands % of Refining Capacity
Baytown	Exxon Mobil	TX	<1,000	--
Beaumont	Exxon Mobil	TX	7,000	2%
Borger	WRB Refining	TX	12,000	9%
Corpus Christi	Valero	TX	<1,000	--
Corpus Christi	BTB Refining	TX	<1,000	4%
El Dorado	Lion Oil	AR	<1,000	1%
Galveston Bay	Marathon	TX	<1,000	--
Garyville	Marathon	LA	38,000	9%
Houston	Houston Refining	TX	<1,000	--
Lake Charles	Citgo	LA	<1,000	--
McKee	Valero	TX	<1,000	--
Navajo	Holly Frontier	NM	2,000	3%
Norco	Shell	LA	<1,000	2%
Pascagoula	Chevron	MS	<1,000	--
Port Arthur	Valero	TX	4,000	2%
San Antonio	Calumet Specialty Products	TX	<1,000	1%
Sandersville	Hunt Oil	MS	<1,000	7%

Table D-4. U.S. Refineries located in PADD 4 (Rocky Mountain) refining oil tar sands (2012 Data).

Refinery Name	Company Name	State	Estimated Tar Sands Usage (bbls/day)	Estimated Tar Sands % of Refining Capacity
Billings	Phillips 66	MT	35,000	70%
Billings	Exxon Mobil	MT	22,000	42%
Cheyenne	Holly Frontier	WY	16,000	39%
Commerce City	Suncor Energy	CO	13,000	14%
Great Falls	Montana Refining	MT	10,000	100%
Laurel	Cenex Harvest States	MT	38,000	73%
Salt Lake City	Chevron	UT	7,000	17%
Salt Lake City	Tesoro	UT	<1,000	1%
Sinclair	Sinclair Oil	WY	31,000	48%
Woods Cross	Holly Frontier	UT	<1,000	4%

Table D-5. U.S. refineries located in PADD 5 (West Coast) refining oil tar sands (2012 Data).

Refinery Name	Company Name	State	Estimated Tar Sands Usage (bbls/day)	Estimated Tar Sands % of Refining Capacity
Anacortes	Tesoro	WA	8,000	8%
Bakersfield	Kern Oil & Refining	CA	<1,000	--
Benicia	Valero	CA	3,000	3%
Carson	Tesoro	CA	<1,000	--
Cherry Point	BP plc	WA	14,000	7%
El Segundo	Chevron	CA	2,000	1%
Ferndale	Phillips 66	WA	20,000	24%
Golden Eagle	Tesoro	CA	2,000	2%
Los Angeles	Phillips 66	CA	19,000	16%
Los Angeles	Tesoro	CA	1,000	1%
Martinez	Shell	CA	5,000	4%
Puget Sound	Shell	WA	4,000	3%
Tacoma	U.S. Oil & Refining	WA	5,000	17%
Wilmington	Valero	CA	1,000	2%

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APPENDIX E. TRENDS IN STATES' CONCERNS AND INITIATIVES

E.1 California

On June 10, 2014, the State of California Interagency Rail Safety Working Group issued their preliminary findings and recommendations for safety in oil transport by rail (State of California Interagency Rail Safety Working Group, 2014). Their preliminary findings and recommendations stated that while the Federal actions taken to date are significant, they do not go far enough to address the risks of increased oil by rail transport. The state should press both the Federal government and the railroad industry to take additional safety measures. Additionally, the state should strengthen its inspection and enforcement resources, remedy significant gaps in its emergency preparedness and response programs, and provide the public with an interactive map showing potential high risk areas from oil by rail traffic.

E.1.1 Recommendations

The Working Group recommends the following: (State of California Interagency Rail Safety Working Group, 2014).

- Improve Emergency Preparedness and Response Programs.
  - Expand the Oil Spill Prevention & Response Program to Cover Inland Oil Spills.
  - Provide Additional Funding for Local Emergency Responders.
  - Review and Update of Local, State and Federal Emergency Response Plans.
  - Improve Emergency Response Capabilities.
  - Request Improved Guidance from U.S. Fire Administration on Resources Needed to Respond to Oil by Rail Incidents.
  - Increase Emergency Response Training.
- Request Improved Identifiers on Tank Placards for First Responders.
- Request Railroads to Provide Real-Time Shipment Information to Emergency.
- Responders:
  - Request Railroads Provide More Information to Affected Communities.
  - Develop and Post Interactive Oil by Rail Map.

E.1.2 Conclusion

The Working Group's report concludes with the following: (State of California Interagency Rail Safety Working Group, 2014)

> *"Transportation of oil by rail has dramatically increased in recent years and will likely continue to increase in the future, both nationally and in California, because of the increased oil production from the Bakken shale and other oil fields. Current regulations and industry practices are not adequate given this recent boom. Minimizing the potentially serious risks of transporting oil by rail will require strengthened Federal requirements, expedited tank car upgrades, and other proactive measures by industry. It will also require additional resources, planning and preparation, and coordination among local and state agencies."*

E.1.3 Letter from California Public Utilities Commission and California Governor's Office of Emergency Services

On April 7, 2015, the California Public Utilities Commission (CPUC) and California Governor's Office of Emergency Services (Cal OES) sent a joint letter to the U.S. Department of Transportation and the Office of Management and Budget stating: (CPUC & Cal OES, 2015)

> *"Today, California filed supplemental comments with the Pipeline and Hazardous Materials Safety Administration that highlight the critical need for the strongest possible standards for tank car safety. Since the U.S. Department of Transportation issued the proposed regulations in 2014:*
>
> - *The frequency of tragic accidents has increased.*
> - *Recent stop-gap equipment and practice improvements have proven insufficient.*
> - *The vulnerability of communities and crucial resources, especially California's precious water resources, has become critical.*
> - *The benefits of existing, proven technologies like thermally protected tank cars and electronically-controlled pneumatic brakes for hazardous materials unit trains, have become even clearer."*

E.2 Minnesota

Minnesota's law creates tougher emergency preparedness standards for pipelines and oil-carrying railroads. It also charges rail and pipeline companies a fee to help equip and train local fire departments to handle oil accidents.

E.2.1 Spill Prevention and Response Plans

Railroads carrying crude oil through Minnesota have to submit spill prevention and response plans to the state pollution control agency, carry out practice drills and comply with other requirements in an emergency. Companies that move oil in the state via rail or pipeline also have to pay a fee to fund training and buy equipment for emergency crews to respond to an oil-train explosion or pipeline rupture.

E.2.2 Push for Minnesota's New Law

Paul Blackburn, an attorney and consultant who helped push for Minnesota's new law, states: (Douglass, 2014)

> *"Essentially, there's no meaningful regulation or requirements or standards for oil spill response for railroads. Instead, decades old Federal regulations continue that for all practical purposes exempt railroads from Federal oil spill response standards. Minnesota recognized that scores of its cities and towns are threatened by crude oil shipments by rail and pipeline, and that local first responders are almost always the first on the scene. To respond to a major spill—such as from an oil unit train [of around 100 tank cars]—is well beyond the abilities of most rural fire departments."*

E.3 New Hampshire

Under New Hampshire's law, which became effective on June 16, 2014, the state gains the power to establish its own, more stringent requirements for inland pipeline spill response plans and equipment (State

of New Hampshire, 2014). "*I think it's pretty much indisputable at this point that what exists at the Federal level is not adequate,"* said Sheridan Brown, legislative coordinator for the New Hampshire Audubon. *"We're happy that there's going to be some state level oversight."* (Douglass, 2014).

In New Hampshire, lawmakers were focused on preventing and cleaning up possible oil spills from just one pipeline: the Portland-Montreal Pipeline, the only hazardous liquids pipeline in the state. The 236-mile line consists of three separate pipes built to carry conventional crude oil from Maine, through New Hampshire and Vermont, and on to refineries in Montreal and Ontario. Two of the pipes are still carrying varying amounts of oil, while a third was retired in 1984 (Welcome to Portland-Montreal Pipe Line, 2014).

What worries state officials and environmentalists is that the Portland-Montreal pipeline could be reversed and used to carry tar sands oil to Maine's coast for export. Canada approved what could be the first part of this plan—a reversal on Enbridge Inc.'s Line 9B so it can deliver Alberta's tar sands to Montreal.

E.4 New York

On April 30, 2014, the State of New York issued a study concerning incident prevention and response capacity (State of New York, 2014).

E.4.1 Findings

The Key Findings of this study were as follows:

- New York State is a major conduit for the North American crude oil boom.
- The transportation of Bakken and Canadian tar sands crude oil present different risks.
- Major recent incidents involving crude oil transportation have heightened national awareness.
- Federal and State agencies have a strong hazardous material safety oversight record, but the sharp increase in crude oil poses new challenges.
- Recently-adopted voluntary measures are incomplete and need to be incorporated into mandatory regulations on an expedited basis.
- Federal Environmental and Contingency Response Plans need to be expanded and updated to account for crude oil.
- Trend and train-specific information is needed to prevent and respond to crude oil related incidents.
- State legislative, regulatory, and operational changes would enhance prevention and response capacity.
- Local response agencies are the first line of defense and need to be properly trained and equipped.

The report details multiple findings and associated recommended actions for safer crude oil transportation and improvements to incident prevention and response. The findings and recommendations were developed by subject matter experts in New York State agencies through a working group process and through interactions with Federal, local, and private partners.

E.4.2 Federal/International Recommendations

- The United Nations, which assigns unique hazardous materials identifiers, should recommend new classifications based on crude oil characteristics to enable appropriate packaging and to inform response personnel as to the qualities of the crude oil.

- The U.S. Coast Guard, U.S. Environmental Protection Agency, and the National Oceanographic and Atmospheric Administration should expedite the update of environmental and contingency response plans.
- The U.S. Department of Transportation should expeditiously amend its regulations to make industrial facility railroads subject to the same standards and inspection protocols as general system railroads.
- The U.S. Coast Guard and the U.S. Environmental Protection Agency should update the delayed Oil Spill Research and Technology Plan as soon as feasible.
- The U.S. Coast Guard should establish a civilian planning position in Sector NY in order to provide organizational continuity to better support New York State-centric preparedness and response.
- The U.S. Coast Guard should review the Vessel Response Plans of the tanker and tugs carrying crude oil in NY State to ensure their response protocols account for the unique risks posed by Bakken and Canadian tar sands crude oil.
- The U.S. Department of Homeland Security should update the authorized equipment list eligible for grant funding to include crude oil firefighting equipment.

E.4.3 New York State Actions

- The State should partner with Federal, local, and industry partners to increase the number, frequency, and variety of preparedness training opportunities and drills.
- New York State should establish a mechanism to obtain more complete information on the volume and characteristics of crude oil being transported and stored in the state.
- The State should develop a one-stop web portal that provides access to emergency points of contact, training, grants, and other preparedness and response resources.
- New York State should partner with Federal, industry, and local response organizations to develop and deploy a comprehensive, geographically-tiered equipment network to ensure timely and effective response in underserved areas.
- New York State should develop a comprehensive database of available crude oil-specific response equipment to support timely and effective response.
- The New York State should partner with the U.S. Environmental Protection Agency and the U.S. Coast Guard to expand upon existing environmental and contingency plans and develop Geographic Response Plans for all areas of the state.
- New York State should promulgate regulations that require placing oil containment booms around waterborne transfers and only allow transfer operations in locations that meet state regulatory requirements or have USCG approval.
- New York State should enact legislation and amend existing regulations to improve rail incident reporting and ensure railroad reporting compliance.
- New York State should develop more effective plume modeling capability to assist first responders.
- DHSES, on behalf of the Disaster Preparedness Commission, should review current federal, state, local, and industry response plans to ensure efficient planning, coordination and application.

E.4.4 Industry Recommendations

- The American Association of Railroads (AAR) in conjunction with the American Petroleum Institute (API) should clarify and expand community engagement requirements outlined but not explained in the voluntary measures undertaken by the railroads.

- Class I railroads should conclude their computer model-based route risk analysis, which accounts for 27 factors affecting the transportation of hazardous material by rail, as soon as practical and update it regularly.

In December 2014, the State of New York issued a status update document reviewing progress on each of the initial report findings.

E.5 North Dakota

The State has proposed establishing a state-run railroad safety program as well as a pipeline integrity program that would complement Federal oversight in North Dakota. The proposal calls for approximately $1.4 million in state funding for three positions to enhance railroad track inspections in North Dakota and another three positions for stepped-up inspections of pipelines that transport crude oil and other liquids to market.

The State implemented a requirement that requires all oil producers in North Dakota to install and utilize oil-conditioning equipment to significantly reduce the volatility of Bakken crude oil. The oil conditioning order includes strict parameters for temperatures and pressures under which the equipment must operate to ensure that light hydrocarbons are removed before oil is shipped to market. The order brings every barrel of North Dakota crude oil within a set standard, requiring oil be stabilized so that its vapor pressure is no greater than 13.7 pounds per square inch (psi) before shipment.

E.6 Washington State

On March 1, 2015, the State of Washington released a report that included 43 findings and recommendations (Washington State Dept. of Ecology, 2015).

E.7 Recommendations for Federal Government

The report proposed the following recommendation applicable to this study:

- The U.S. Coast Guard should establish a long-term waterways management plan to accommodate increased vessel traffic and an appropriate vessel traffic service for the waterways of Grays Harbor, Columbia River, the Salish Sea and the outer coast.

E.7.1 HB 1449, Oil Transportation Safety Act

On April 24, 2015, the Washington State legislature passed HB 1449, Oil Transportation Safety Act. The Governor stated:

> *"This bill means our first responders will get advanced notification when oil trains are coming through, and it also expands the barrel tax on crude oil and petroleum products to include both rail and marine. This means that at a time when the number of oil trains running through Washington is skyrocketing, oil companies will be held accountable for playing a part in preventing and responding to spills."*

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APPENDIX F. COMMENTS FROM GREAT LAKES COMMISSION

The following are highlights from the Great Lakes Commission report's findings focused on key issues that may warrant further study and action on the part of government agencies and industry (Great Lakes Commission, 2015a; 2015b; 2015c; 2015d).

F.1 Oil Extraction and Movement

- There are conflicting opinions about the characteristics of crude oil, which is relevant to the perceived safety of the transportation process by rail.
- The characteristics of Alberta oil sands present particular challenges in the transportation of the product by all modes.
- Crude oil passes directly through the region to refineries located elsewhere.

F.2 Risks and Impacts of Oil Transportation

- There is a need to better understand the relative risks of oil spills associated with increased transportation of crude oil.
- The risks and costs of increased oil transportation to government agencies need to be studied and better understood.
- The age and quality of infrastructure is a concern for most modes of oil transportation, which poses an increased risk for a spill or accident.
- Communications between oil companies, oil transporters, and regulatory and response agencies is important but is often lacking and can be better coordinated to help improve preparedness and reduce the risk from spills.

F.3 Oil Transportation Programs, Policies and Regulations

- The increase in oil production and transportation, particularly rail transportation of oil, is outpacing the development and implementation of regulatory, enforcement, and inspection programs.
- A review of the funding and adequacy of inspection and enforcement protocols and the timeliness of spill reporting across all modes will help identify gaps in regulatory, prevention, and response programs.
- The Great Lakes states and provinces are not taking full advantage of opportunities to assume oversight of pipeline safety, inspection, and enforcement.
- Plans to retrofit and/or eliminate DOT-111 tank cars and replace them with newer, safer models will significantly improve the safety of oil transportation by rail.
- Pursuing additional improvements to rail transportation safety, including adopting new technologies and dual person crew requirements may help lessen the number of rail accidents.
- Proper classification of all types of oil transported by train is necessary.
- Federal, state, and provincial response agencies may not be adequately funded and equipped to efficiently respond to spills from different modes and in all locations.
- Some mechanisms for communication, coordination, and notification between jurisdictions regarding oil transportation and spills currently exist and may be expanded to further enhance preparedness and response in the region.

Vessel Response Plans (VRPs) required under the Oil Pollution Act (OPA) represent one important component of the U.S. regulatory regime that ensures safe transportation of crude oil by vessel. It is unlikely that VRP requirements can presently be met for transport of heavy crude oil on the Great Lakes.